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GIS DECISION SUPPORT FOR INTEGRATED COASTAL MANAGEMENT

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Integrated Coastal Zone Management - Marine Protected Areas - Marine Environmental Quality

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Abstract

The coast is subject to increasing pressure from a multitude of often competing users. Coastal managers are faced with the challenge of balancing the distribution and activities of users. They must take into account user conflicts, environmental impacts, socio-economic benefits and the voices of the coastal community. On another stream, Geographic Information Systems (GIS) are being heralded as decision support tools. These tools range from inventory warehouses to dedicated Spatial Decision Support Systems (SDSS) to impending Collaborative Spatial Decision Making Systems (CSDMS) for decision-making groups. This Report investigates the marriage of these two fields, coastal management and GIS, through the development and implementation of a pilot Coastal SDSS for multiple-use management.

The investigation was pursued by exploring the component parts of a Coastal SDSS: (1) the decision makers and process within which they function; (2) the analysis upon which decisions are made; and (3) the data which are analysed and in themselves contribute to an understanding of the decision problem and solution. Information and observations for each of these components were gathered and woven together from five sources: (1) literature survey; (2) a two-phase questionnaire of coastal decision makers; (3) interviews of participants of a resource management multi-stakeholder process; (4) non-participant observation of an ongoing coastal management process; and (5) two workshops involving the implementation of a pilot Coastal SDSS to evaluate its effectiveness for group-based coastal management. The workshops, involving members from eight stakeholder groups, formed part of a current coastal management initiative in Barkley Sound, Vancouver Island. The pilot Coastal SDSS included the development of position analysis and multi-criteria analysis models accessed from a customised interface. The results from the workshops were assimilated with previous findings into design and implementation specifications of a Coastal SDSS.

Twenty-one specifications are made for the development and implementation of a Coastal SDSS under the categories of: 1) format; 2) decision making; 3) analysis; and 4) data. A chauffeur-driven system is advocated as the preferred format of implementation directed by a GIS facilitator and GIS analyst. Of critical importance to the successful implementation of a Coastal SDSS is adequate preparation of technical accessibility for participants. The decision making approach of a Coastal SDSS should lie in the generation and evaluation of alternatives with an emphasis on graphic communication and dynamic decision making. The analytical component of a Coastal SDSS must balance quantitative analysis with qualitative, and deterministic with interactive. Analytical specifications recommended include capability analysis, spatial coincidence, multi-criteria analysis, consensus evaluation, alternative evaluation, environmental modeling and generic GIS functionality. The points of emphasis for the data component include a taxonomy of coastal inventory with particular reference to coastal use and administrative framework, representation of the coast as a continuous transition zone between marine and terrestrial environments, cartographic communication geared towards decision making, and a metadata strategy for managing data quality.

The research concludes that Coastal SDSS can fill a void in and enhance coastal management, particularly with respect to supporting communication and objective spatial analytical methods. However, decision makers were cautious in embracing a central role for Coastal SDSS. Their concerns can be addressed by involving the full range of coastal decision makers in

the design and development of Coastal SDSS particularly through experimental research design and by incorporating GIS into coastal management curricula.

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1.0 INTRODUCTION

> Roll on, thou deep and dark blue ocean - roll!
> Ten thousand fleets sweep over thee in vain;
> Man marks the earth with ruin - his control
> stops with the shore.
>
> George Noel Gordon, Lord Byron
> (*Childe Harold's Pilgrimage*, Canto IV, 1818)

1.1 THE EXHAUSTED COAST

At the interface of marine and terrestrial environments, the coast has seemed infinite in its capacity to support human endeavour and beyond our realm of control. The natural

characteristics of the coast have long been utilised and enjoyed (Charlier and Charlier, 1989; Clark, 1995; Agardy, 1993; Halsey and Abel, 1990; Healey and Zinn, 1985). Long-standing, traditional uses include fisheries, transportation and waste disposal. More recent ventures include mariculture, oil and gas exploration, marine parks, and tourism and recreation. Led by a demographic shift predicted to bring 80% of the world's population to within 50 km of the sea by the end of the 20th century, multiple use of the coast is set to continue and perhaps intensify (Charlier, 1989). Whether or not the coast is beyond our control, it is not beyond impact as assured Byron (Gordon, 1818). It is clear, that despite its perceived vastness in both space and resources, the coast is not infinite in its capacity to accommodate these pressing, multiple demands. Numerous examples of competition for space, over-exploitation of resources, degradation of natural habitats, and user conflicts attest to this increasing exhaustion of coastal space and resources (Goldberg, 1994; Johnson and Pollnac, 1989; Healey and Zinn, 1985; Wolf, 1985). These impacts are made more acute by incompatible environmental, economic, social, and philosophical priorities within the wide-reaching coastal community.

In an attempt to control these pressures (if not the coast itself), integrated coastal management (ICM) gradually evolved and was formalised through the U.S. *Coastal Zone Management Act* (CZMA) in 1972. Though variously defined and labeled, the primary goal of ICM is to prepare comprehensive strategies which attempt to balance environmental considerations and human use of the coast (Kenchington, 1990). One of the components of ICM is *multiple use management to facilitate the equitable and shared accommodation of various activities within a region*. This often is approached through the development of *a spatial zonation plan in which areas of the coast are segmented such that compatible uses are congregated and incompatible uses are segregated*. Among other elements, a coastal management plan requires an extensive inventory of resources and uses, and a knowledge of the interaction and impacts between users and the resources, and between different user groups. In addition, co-operation among relevant jurisdictional agencies each of whom has a mandate over portions of the coast is required.

Despite the global proliferation of coastal management strategies, twenty years since passage of CZMA, efforts are still focused on establishing guiding principles of ICM (OECD, 1993; World Bank, 1993). Relatively less effort is spent on avenues and techniques to implement them, although there is evidence that attempts are being made to consolidate a coastal manager's toolbox (Clark, 1995). Nevertheless, the predominant mood is captured by Graham and Pitts (1997, Executive summary): "The principles embodied in the philosophy [of coastal management] are not built into the decision-making that occurs as part of the planning process". The result is that, with few exceptions, multiple-use coastal management remains a complex, inconsistent and apparently *ad hoc* decision process susceptible to dissatisfaction and allegations of unfairness (Knecht, 1990; Byrnes, 1991).

1.2 GEOGRAPHIC INFORMATION SYSTEMS - THE HERALDED TOOL

Spatial planning, which forms an integral part of ICM in developing zonation plans, involves the location of activities and allocation of space for a single use or variety of uses. Geographic Information Systems (GIS) have emerged in the last 30 years as tools to assist planners in the data management and analytical tasks involved in spatial planning. Like any other computerised information system, GIS can input, store, edit, manipulate and output data. There are two defining characteristics which distinguish GIS from other information systems and graphic technologies (Maguire, 1991; Fisher and Lindenberg, 1989; Cowen, 1988). Firstly,

the spatial data in GIS are explicitly linked to attribute (descriptive) data. Thus, one can perform the above-mentioned information system functions on both databases. The geographic

inventories which can be graphically displayed for communication. Secondly, unlike some graphic packages which manipulate images, the data in GIS possess 'intelligence' regarding

the overlay, previously not afforded (Maguire and Dangermond, 1991). These characteristics of GIS have been capitalised upon in a variety of planning applications such as cadastral

applications is growing continually and rapidly.

Towards this progression within the planning domain, GIS are heralded as decision support

which delivery route to take, where to locate a school, and how to zone for land use plans. The line between an inventory tool, an analytical tool and a decision support tool is a narrow and

choice implications, is decision support. Another problem associated with the application of GIS is the tendency to put the cart before the horse. "We have a GIS. What can we do with it?"

in a flourish of GIS applications termed 'Decision Support Systems' with varying degrees of decision support.

Spatial Decision Support Systems (SDSS) (Densham and Goodchild, 1989). SDSS are designed for specific ill-structured spatial problems. These types of problems generally are solved

of a data management core, usually GIS, supplemented by analytical modules, and accessed by customised interface. The main emphasis in the development of SDSS is on the availability of

dichotomy exists in this regard. On the one hand, it is argued that beyond basic spatial manipulation, GIS are limited in providing spatial analysis (Openshaw 1991).
much emphasis is being placed on incorporating advanced spatial analytical capabilities. On the other hand, it also can be argued that only limited GIS analytical capabilities are used in

is needed on customising and taking full advantage of existing capabilities within a decision-making framework.

generation of GIS-based decision support tools, namely collaborative SDSS (CSDSS)
GIS are used more directly by a group of decision-makers who may not be proficient in its use (Densham , 1995). Initial efforts in CSDSS development have focused on the incorporation of the system within the complex group decision-making process and decision-makers'

decision-making processes.

The evolving role of GIS has prompted the debate whether GIS is a tool or a technology or a

regarded as computer tools, and perhaps prematurely considered a technology and a discipline

in itself. The increasing prominence of remote sensing, the exploration and development of spatial analyses, and the increasing use of GIS and remote sensing in decision-making, warrant the consideration of GIS as a tool within the wider discipline of geographical information sciences.

1.3 NATURE OF THE STUDY

Research Objectives

The methodological challenges associated with multiple-use coastal management and the potential of GIS to contribute as a decision support tool represent the two converging streams of this study. The over-riding goal addressed is *to investigate the marriage of these two fields within a coastal spatial decision support system (Coastal SDSS).* Specific research objectives are:

1. to develop a conceptual design of a GIS-based decision support system to facilitate multiple use coastal zone management; and

2. to augment and refine the conceptual design with a pilot implementation in an actual multiple-use coastal management initiative.

Driving the research is the decision problem addressed: multiple use of the coast including the environment and the various users. This emphasises the philosophy of this research, *to be grounded in the problem prior to investigating a GIS tool.* Within the research framework, resolution of multiple use is facilitated by a Coastal SDSS, and the decision-makers.

Central to the Coastal SDSS is the decision problem and its representation within the system. Surrounding it are:

1. the decision-making approach;
2. the analysis required which will contribute to the decision; and
3. the data required to fuel the analysis.

These three elements represent the first three areas of investigation. Although described as discrete components, there is definite interdependence among the three elements requiring feedback. The computer and people represent the fourth area of focus:

4. integration of the three Coastal SDSS elements and incorporation of the system within the decision-making process.

Research Questions

The previously discussed areas are addressed in terms of technical requirements and user expectations through the following primary and subsidiary research questions:

(1) *What are the decision-making requirements of a Coastal SDSS?*

What is the decision-making format and process of multiple-use coastal management?
What are the tasks involved?
Who are the decision-makers?
What are the expectations of decision-makers towards the use of GIS for decision-making?

(2) *What are the analytical requirements of a Coastal SDSS?*

What techniques and methods are currently employed in multiple-use coastal management?
How can these techniques be characterised for suitability with GIS?
What new techniques can be developed using GIS?
What are the expectations of decision-makers towards the use of GIS for analysis?

(3) *What are the data requirements of a Coastal SDSS?*

What type of information is required in a coastal management inventory?
Can GIS accommodate these data requirements?
How important is data quality in decision-making?
How can data quality be appropriately evaluated?
What are the expectations of decision-makers towards the use of GIS for inventory?

(4) *How can the preceding three fundamental elements be incorporated in a dedicated Coastal SDSS?*

Can the elements be incorporated using GIS?
What is a suitable interface to access the Coastal SDSS?
How can decision-makers best interact with a Coastal SDSS?
What is the role of a Coastal SDSS within a decision-making process?
What are the expectations of decision-makers towards the role of a Coastal SDSS in coastal management?

The answers to these questions will produce technical specifications and implementation strategies for a Coastal SDSS.

Limitations and Delimitations

This research attempts to bring together two fields each of which is in itself broad and multi-faceted. As a result, and as is the nature of the coastal environment itself, this research has been susceptible to non-discrete boundaries upon which limitations and delimitations have had to be imposed. The topics in these two fields include among others: resource management, decision-making theory, conflict resolution, spatial environmental modeling, zonation modeling, SDSS architectural design, and the interaction of humans with computers. Although each of these topics alone could constitute a worthy research endeavour, the intent of this study has been to provide a comprehensive account. In doing so, this study has sacrificed scrutiny in many of these interesting avenues.

1.4 RESEARCH CONTRIBUTIONS

The research undertaken in this study contributes on several fronts relating to coastal management, the role of GIS in a decision support capacity, and the development of a Coastal SDSS. As mentioned earlier, the philosophy of this research is problem driven, the impetus being to contribute a tool which improves the way multiple-use coastal management decisions are reached. The techniques investigated and developed will strengthen the structure that is currently deficient in coastal management decision-making and will provide input into the fledgling coastal manager's toolbox. Although the problem focus of this research is multiple-use coastal management, there are many shared characteristics with other resource management fields, such as the allocation of space and resources, and the group decision-making process, which can benefit from the results of this research.

While the decision-makers' perspective is heavily emphasised throughout this study, technical aspects of a Coastal SDSS are also advanced. One area advanced is in the management of data quality in GIS relevant to decision-making. This research advances the way in which GIS is used as a decision support tool: in some aspects expanding the role; in others, making expectations more realistic in terms of its much-heralded decision-making capabilities. Other contributions of the research include the incorporation of tailored analytical techniques with GIS and the shedding of new light on the research directions of collaborative spatial decision-making identified by the National Center for Geographical Information Analysis (NCGIA) research initiative (Densham *et al.*, 1995).

Eight years ago, Basta (1990) suggested that the combination of information, science, technology and decision-making through experimental research was a legitimate and required area in coastal management. He emphasised that in this type of research "People are the keys. The key is not the toys" (Basta, 1990: 313). While the application of GIS to coastal management and decision-making in general are growing fields, there is no evidence of experimental research with regards to implementing this technology. The fundamental contribution of this research is to fill the void identified by Basta through the pilot implementation of a GIS-based decision support system for coastal management.

1.5 DOCUMENT ORGANISATION

Section Two sets the context for this research by reviewing significant and recent literature relating to coastal management and GIS as a decision support tool. Section Three describes the research design and procedures undertaken to answer the research questions identified earlier in this section. Sections Four, Five and Six present the foundation of the research, namely the three components of a Coastal SDSS as enumerated in the first three research questions: decision-making, analysis and data. Section Seven incorporates the results into design and implementation specifications of a Coastal SDSS as specified in the fourth research question. Section Eight concludes the report by presenting the main findings of the research and making suggestions for future directions towards a Coastal SDSS.

2.0 W

2.1

The development of a coastal spatial decision support system (Coastal SDSS) for multiple-use management spans a broad range of fields. This section reviews and ties in the relevant

considers the nature of and approaches to multiple-use coastal management (Section 2.2 and Section 2.3). Section 2.4 reviews coastal information systems. This leads into a discussion on the

Section 2.6 discusses recent developments in coastal and marine GIS. The key points and literature are summarised in Section 2.7.

MULTIPLE USE ON THE COAST

> *Coastal Zone* is that space in which terrestrial environments influence marine (or lacustrine) environments and vice versa. The coastal zone is of variable width and may also change in time. Delimitation of boundaries is not normally possible, more often such limits are marked by an environmental gradient or transition. At any one locality the coastal zone may be characterised according to physical, biological or cultural criteria. These need not, and in fact rarely do, coincide.
>
> (Carter, 1988: 1)

From its very definition (of which there are many) the coast represents a challenge: a challenge to explore, a challenge to utilise, a challenge to manage. Depending on the biophysical or political parameters imposed, the coastal zone can extend seaward from the edges of the continental shelf and landward to the limits of watershed boundaries. Its vastness in space and resources belies an infinite capacity and resilience to support human endeavour. From the earliest times of human settlement, the coast has been a source of food and materials; a means of transportation, security and communication; a site for industrial development; and a depository for wastes. At the same time it is the destination for tourists and recreational enthusiasts and a target for conservationists and environmentalists. Each interest occupies a niche in the coastal zone, the extents of which are defined by ecological, physical, economic and/or social criteria. Where the occurrence of these criteria for different interests overlap, there exist two possible outcomes. The interests are complementary and can co-exist, or their occurrence is conflicting.

Conflicts can arise among users, or between users and the environment. Coastal conflicts have been classified as (Johnson and Pollnac, 1989; Sorensen, 1971):

- competition for resources;
- competition for space;
- impact from by-products; and
- conflict in values.

Competitive demands on the same resource or linked resources are perhaps the most evident. Examples of competitive conflict for the same resource include First Nations[2] and commercial fishing, or dunes used as an erosion buffer and for beach front houses (Chapman, 1991).

Competition for linked resources might involve fisheries for species in predator-prey relationships (Orbach, 1989). Activities which require sheltered waters with adequate flushing,

weather season might temporally conflict with peak fishing periods (Cicin-Sain and Tiddens, 1989). By-product conflicts arise from the activities of one group indirectly impacting the

impacts from fishfarms on recreational interests (Bennett, 1991), or siltation from logging operations clogging stream beds.

differences, or from differences in the perception of facts. These arise when groups place differing priorities and importance on the environment and its use, most often pitting

value differences of biological resources were the source of conflict between "overzealous conservation minded divers" and commercial fishermen (George and Nichols, 1994). The

Engineering, 1995; Flood *et al.*,
philosophical differences, usually between direct and indirect users, remain the most intractable to resolve (Cicin-Sain and Griffman, 1982).

characteristic of the coastal region:

- Coastal areas are among the most densely populated regions. There is increasing migration from inland areas by people seeking economic and social opportunity, and

  finite in space and resources to accommodate these demands (George and Nichols, 1994; Goldberg, 1994; Agardy, 1993).

  Dynamic nature
  The marine environment is dominated by efficient vertical and horizontal transport

  ecological linkages and wide-ranging geographical impacts from perturbations and interactions. In addition, this dynamic medium makes it difficult to impose boundaries

  Ricketts, 1988).

- *ting*
  Traditionally coastal resources and activities have been managed on a sectoral basis

  comprehensive considerations. In addition, legislative fragmentation, duplicity of authority, and uncertainties of jurisdiction, all operating in a vacuum of coastal policy. *et al.*, 1994). The

  requires a shift in institutional setting which lags behind management direction.

-

The public has traditionally enjoyed common property rights and inherent freedoms of the seas. The relatively recent practice of occupation of coastal spaces, such as leases, can alienate other users and violate these long-standing rights. On the other hand, upholding these rights and freedoms unmanaged might be counterproductive to their enjoyment (Tibbetts *et al.*, 1995; Seabrooke and Pickering, 1994; Agardy, 1993; Swanson *et al.*, 1978).

- *Information*
  Some argue that the marine environment represents the last frontier of discovery, hence its management is subject to a lack of information (Earle, 1995; Cendrero, 1989). Others argue that communication and assimilation of available information, rather than lack of information, is the problem (Furness, 1994; Basta, 1990; Ehler, 1990). In addition one must consider the suitable quality of available information. Regardless, coastal conflicts are often fueled by misinformation or incomplete information (Flood *et al.*, 1994; Byrnes, 1991; Cicin-Sain and Griffman, 1982).

- *Cumulative environmental impacts and public awareness*
  Increasing knowledge of cumulative environmental impacts and a demand for public involvement and community management has heightened awareness and desire for action (Flood *et al.*, 1994; Kelly *et al.*, 1987).

2.3 MULTIPLE-USE MANAGEMENT

Integrated Coastal Management

Traditionally, the management of coastal interests has been approached by sectoral and reactive crisis management motivated by economic gain (Charlier and Charlier, 1995; Agardy, 1993). In response to short term successes, calls have been made for a comprehensive strategic approach, namely integrated coastal management (ICM) (Salasan *et al.*, 1993; Cotten and Smillie, 1992; Rickets, 1992; Day and Gamble, 1990; Kenchington, 1990; Hildebrand, 1989). ICM has been formally defined as:

> a dynamic process in which a co-ordinated strategy is developed and implemented for the allocation of environmental, socio-cultural and institutional resources to achieve conservation and sustainable multiple use of the coast.
>
> (Coastal Area Management and Planning Network, 1989)

The central objectives of ICM are to accommodate multiple use, while:

- protecting and enhancing the resource base and marine environment in general;
- optimising socio-economic benefits; and
- avoiding or minimising user conflicts (Kenchington, 1992; Cicin-Sain and Knecht, 1998; Susskind and McCreary, 1985; Wolt, 1985).

Decision-makers are therefore faced with balancing these conflicting objectives.

Much effort has been focused on describing goals and policies of ICM (OECD, 1993; World Bank, 1993). Although many steps have been taken towards achieving those goals, by and

rare, partially due to the complexity of the task and the global diversity of coastal regions. Nevertheless, there are generally two common denominators in ICM strategies, namely

Multi-party Task Forces

As with the trend in resource management processes, ICM is increasingly undertaken by a

jurisdiction and (2) the increasing calls and recognition for more direct non-governmental involvement in the decision-making process. Jurisdiction in the coastal zone is legislated for a

many jurisdictional responsibilities overlap on the coast. For example, in British Columbia there are at least sixteen federal, provincial, local and First Nations agencies responsible for

River Estuary Review Committee and the Marine Environment and Resource Management Commission of the Great Barrier Reef Marine Park are established to co-ordinate the activities

In parallel to inter-governmental harmonisation is a trend toward public involvement. Previously, public involvement was carried out through consultations. Increasingly now, direct

is being demanded (Brooke, 1995; Flood *et al.*
1993; Vande Vusse, 1991). This is spurred by the recognition that the wide-reaching coastal community, including both direct and indirect users, has a stake in coastal management

modus operandi

of these task forces is generally consensus based. Through the consensus process acceptable

relevant parties in which compromises and trade-offs are made (Estes, 1993, Darling, 1993; Kochery 1993; Winch, 1993; BC Round Table on the Environment and Economy, 1991; Dorcey, 1986; Susskind and McCreary, 1985). Percy (1994: 775) notes that "pre-requisites for such

availability of user-friendly computer tools that permit non-specialists to rapidly and efficiently retrieve and apply large amounts of information".

Various regulatory mechanisms, such as permits, taxes, harvesting licences, catch limits, temporal allocation, discharge limits, economic targets, environmental quality standards, and

1988; Healey and Zinn, 1985). Another common tool for ICM is spatial allocation. The usual outcome is a zoning strategy in which the coastal area is divided into regions for which a

physical suitability, the identification of multiple compatible uses, "making rational choices among incompatible uses", and pressure exerted by special interest groups (Marine Science

Multi-use zoning can be developed at two spatial levels: (1) regional zoning which usually defines strategic planning areas; and (2) local zoning which defines specific site planning within regional zones (OECD, 1993; Cendrero, 1989). In many cases, zoning is carried out under the auspices of marine protected areas (Agardy, 1993; Ricketts, 1988). There are generally three types of zones each with specific and different objectives: (1) conservation and preservation, (2) single sector use; and (3) multiple use. Conservation and preservation zones are often zoned as core areas allowing limited if any activities. Single sector use and multiple-use zones are zoned as buffer areas, and determined by the complementarity of various activities to be accommodated in the same zone without negative impact. Complementarity matrices have long been used towards this end (Ellis, 1972; Sorensen, 1971). Perhaps the most successful zoning strategy was developed for the Great Barrier Reef Marine Park (GBRMP) (Cocks, 1984). The success of this example has been attributed in part to pre-existing consensus on the over-riding national and international environmental value of the reef and the size of GBRMP being able to physically accommodate all desired uses (Agardy, 1993).

Coastal zoning has primarily focused on onshore areas, however, increasingly offshore areas also are zoned, if not in a legal sense then as guidelines. The traditional rights and freedoms enjoyed by the public in the coast has meant that zoning the coastal region has been met with some resistance. To some, the concept of zoning has a threatening overtone of regulatory control and raises inherent difficulties of spatial delineation. To counter these concerns the term 'coastal *zone* management' is often replaced by 'coastal management' or 'coastal area management'. Nevertheless, the development of zoning strategies remains as one of the most utilised mechanisms for multiple-use coastal management.

Multiple-Use Techniques

Byrnes (1991) suggests that there are three essential ingredients for coastal conflict management: (1) desire for agreement and co-operation; (2) communication and negotiation skills; and (3) analytical tools. Although the guiding principles of ICM are now being consolidated, the same cannot be said for the analytical techniques and models used to implement the principles, and to develop multiple-use strategies. The decision-making process of ICM has been shrouded in terms such as brainstorming, negotiation, bargaining, compromise and consensus building and an apparent lack of analytical structure (George and Nichols, 1994; Byrnes, 1991; Orbach, 1989; Susskind and McCreary, 1985). This gives the impression that coastal management decisions are made on an *ad hoc* basis within an analytical 'black box' making them susceptible to dissatisfaction, suspicion and allegations of unfairness in the allocation of coastal spaces and resources to the various users (Byrnes, 1991; Knecht 1990).

Instead of a coherent coastal managers' toolbox there exists an array of analytical techniques used in formulating coastal management plans. Most of these are extended from land-based planning. The techniques can be divided between those which are directly related to developing spatial zoning schemes and those which contribute aspatial analytical results. The most common spatial tool is the development of thematic atlases of the distribution of resources and use discussed further in Section . Other spatial techniques include:

- delineation of homogeneous coastal units by integrating, usually biophysical, criteria (Cendrero, 1989; Amir, 1983);

spatial coincidence of uses (George and Nicholls, 1994; Berry, 1993; Clark, 1990; Hatcher *et* 1990);

-
- weighted/scaled map combination to evaluate capacity, impact and suitability (Cendrero,
- multi-objective programming (Stough and Whittington, 1985); and
  SIRO-PLAN - satisfying policy of iteratively assigning mapping units to a zone (Cocks,

GIS have been used conduct analysis for coastal management particularly to evaluate spatial coincidence of uses and suitability assessment. These are further discussed below.

include:

-
- environmental impact assessment;
  adaptive management;
- 92; Price, 1990);
-
- demand forecasts (Feitelson and Elgar, 1991);
  multi-attribute trade-off analysis (Byrnes, 1991);
-
- weighted multi-criteria (Chapman, 1991);
  cluster analysis (Price, 1990);
-
- ABC Resource Survey Method (Lawrence , 1993); and
- r, 1991).

Recent attempts to compile some of these techniques into a coastal managers toolbox include *Coastal Zone Management Handbook*.

COASTAL INFORMATION SYSTEMS

components, is necessary before any sound multiple-use management can be achieved (Ricketts, 1992). Clark (1995) goes so far as to note that "Coastal management programs are

characteristics and processes, biological resources, current uses, socio-economic profile and administrative setting (Hale, 1991). The management of data requirements and compilation of

addition to contributing to the understanding of the environment and potential impacts of development, the compilation of an inventory also ensures a common information base for all

arise can be avoided (Byrnes, 1991). The initial concept of data requirements for coastal management and coastal information systems was seeded over twenty years ago with the work

Some argue that coastal data, especially for the marine environment, are limited (Earle, 1995; Cendrero, 1989). However, others argue that marine scientists are in fact adrift in "oceans of data" (Furness, 1994; Ehler, 1990). Taken further, it is also argued that coastal managers are operating in a state of 'data anarchy' in which there is a profusion of *data* but very little *information* useful for decision-making (Byrnes, 1991; Basta, 1990; Ehler, 1990; Kelly *et al.*, 1987). The need has been identified to capture the non-scientific knowledge base and present the information directly to decision-makers in a format which is understandable and which will contribute to the decisions. An additional argument to this debate focuses on data accessibility. The apparent dearth of coastal and marine information has been attributed not to lack of data, but rather to available data being trapped by institutional, technological and political factors which impede access (Furness, 1994). One approach to overcome these impediments is the creation of database directories and networks (O'Donnell, 1996; ACZISC, 1994; Blyth *et al.*, 1993; Harper *et al.*, 1993; McBride *et al.*, 1991).

Once the problems of data access are overcome, building a coastal zone inventory involves constructing an intelligent and cohesive mosaic by integrating numerous separate data sources. However, it is often found that the databases are incompatible and inconsistent which hinder the process of inventory building. Differences in data collection equipment and protocol, scale, projection, temporal and attribute resolution, terminology and nomenclature, data gaps, problem solving approaches and quality control standards, especially data validity, tolerances of error and uncertainty need to be resolved before integrated databases can be compiled (Canessa and Keller, 1993; Shepherd, 1991; Kuehlthau and Herring, 1990; LeBlanc *et al.*, 1990; Roberts and Ricketts, 1990). Problems of data inconsistency can supersede those of data availability, accuracy, geographical coverage, large data volumes and lack of structure (Shepherd, 1991).

Traditionally coastal inventories have been compiled as atlases (see for example Dickins *et al.*, 1990), and more recently as digital coastal information systems. These have culminated in the development of large digital atlases such as the North Sea Project Database (Green, 1995) and United Kingdom Digital Marine Atlas (Schmidt-Van Dorp, 1993). It is not surprising that GIS have emerged as valuable media for coastal zone inventories, most notably for the ability to store the diverse amount of data required for coastal management in an integrated format. As a result, GIS were introduced to the coastal management community as a vessel to maintain coastal data (Haddad and Mitchener, 1991; McBride *et al.*, 1991; Welch *et al.*, 1991; LeBlanc *et al.*, 1990; Roberts and Ricketts, 1990; Coleman *et al.*, 1989). Traditional digital atlases have been augmented with multimedia video, remote sensing images, photographic images and hypertext medium (Damoiseaux, 1995; Finkl and DaPrato, 1994; Howes, 1993; Ji *et al.*, 1993; Welch *et al.*, 1992).

2.5 GIS FOR DECISION SUPPORT

Almost from their initial development in the 1960s GIS have been heralded as decision support technology (Jankowski, 1995; Eastman *et al.*, 1993; Janssen and van Herwijnen, 1989; Cowen, 1988), even as "essential" technology for decision-makers (Mumby *et al.*, 1995). Others argue that there is a fundamental lack of spatial analysis for GIS to be truly effective decision support tools (Carver, 1991; Openshaw, 1991; Densham and Goodchild, 1989). The arguments are perhaps based on semantics in terms of degree of decision *support* from provision of

GIS as decision support tools can be considered "the most important application of GIS in the future" (Scholten and Van der Vlugt, 1989: 304).

Burrough, 1987). This is particularly attributable to this information technology's effective infinite precision, the capability to change scale, the capability to combine and overlay data

separation of decision-makers from the actual use of GIS (Sussman, 1994; Goodchild and Gopal, 1989; Abler, 1987; Burrough, 1987). Just those capabilities which are most alluring are

From Inventory to Decision Support

GIS clearly, and some say 'naturally' or 'automatically', are evolving from an inventory-based

focus, to becoming a decision support tool within a broader decision-making environment (Eastman, 1993; Clarke, 1990; Dickinson, 1990; Parent and Church, 1987), including land use *et al.*, 1995; Berry, 1993). Two roles of GIS decision support can be

Maps are a fundamental component of GIS. They also form a major basis for decision-making. They are a means of communication between researchers and decision-makers, and between

or interactive display and query. In noting the limitations of cartographic display types available in GIS, Armstrong (1992) developed a functional taxonomy of cartographic displays required by decision-makers at various stages of the decision-making process.

information about the study area to assist decision-makers to identify the problem. Monoplan displays such as spider maps show a single solution and are used to explore alternative plans.

ease with which one can create maps with GIS and the inexperience of many users in cartographic design can lead to the production of ineffective and misleading maps (Green,

the incorporation of knowledge or expert- based map design software within GIS (Weibel and Buttenfield, 1992).

buffering and overlay. Johnston *et al.*
statistical) procedures and techniques applied in locational analytical work. In this regard, GIS do support some spatial analytical techniques such as nearest neighbour, network analysis and

regression as well as non-spatial techniques such as multi-criteria analysis (Carver, 1991). Although there is an emphasis to augment the analytical dimension of GIS decision support

culture, perceptions, information access systems and language must also be considered as an integral part of GIS decision support development.

There are two not necessarily exclusive perspectives on developing better decision support capabilities: one is based on integration of specialised analytical models with GIS, the second is based on analytical problem solving as a centrepiece of Spatial Decision Support Systems (SDSS) (Jankowski, 1995).

Multi-Criteria Decision-Making

Many public planning options are characterised by multiple and conflicting objectives for which is there is no optimal solution. Single criterion optimality has been replaced by pareto-optimality in which there is a broader set of more or less acceptable alternatives. Multi-criteria analysis (MCA) is one group of techniques which allows decision-makers to analyse the complex trade-offs among the objectives, generate alternative solutions, take into account decision-makers' preferences and evaluate alternatives based on multiple decision factors (Voogd, 1983). Numerous MCA techniques exist. Given the available comprehensive reviews such as found in Massam (1993), Nijkamp *et al.* (1990), Vincke (1986), Cohon (1978) and Edwards (1977), an in depth discussion is not repeated here. However, certain key aspects of MCA are discussed in light of GIS.

The first step in MCA is to identify the criteria upon which to generate and evaluate alternatives. Several standardisation techniques can be used for comparison and manipulation of criteria with different metrics (Voogd, 1983) avoiding the need for a common metric, most often monetary, used in cost-benefit analysis. In GIS these criteria are represented as data layers or attribute values. Subsequently the criteria can be weighted according to the degree of importance of each criterion. Criteria valuation is perhaps one of the most important components of MCA (Pereira and Duckstein, 1993). However, there is always a degree of uncertainty and inconsistency surrounding the subjective valuation of criteria and, therefore, sensitivity analysis is a key step in examining the stability of preferences (Jankowski, 1995; Carver, 1991). GIS generally lack the ability for interactive criteria valuation as in MCA software. However, they do offer the capability to assign weights based on neighbourhood and distance functions (Pereira and Duckstein, 1993). There are several techniques for capturing decision-makers' preferences in both qualitative and quantitative forms (see Appendix X). The scale of measurement will determine the type of analysis which can be applied. For each alternative, criteria weightings are compiled most simply in a linear utility function (weighted summation) or non-linear utility function such as multi-attribute utility. Other approaches for evaluating alternatives include concordance analysis or pairwise comparison such as the Analytic Hierarchy Process (AHP) (Saaty, 1980).

Despite the potential of MCA for solving spatial problems with GIS particularly through the generation and evaluation of alternatives, there are only a handful of applied examples to draw upon (Strapp and Keller, 1996; Brown *et al.*, 1994; Pereira and Duckstein, 1993; Campbell *et al.*, 1992; Janssen and Rietveld, 1990). Current GIS are capable of dealing with multiple criteria through deterministic overlays involving numerous data layers representing criteria based on suitability analysis (McHarg, 1969). While the deterministic overlay identifies feasible solutions there is no indication of the most appropriate sites within the feasible set as the relevant importance of criteria cannot normally be accommodated. Instead threshold values must be defined (Carver, 1991; Janssen and Rietveld, 1990). One exception is the weighted overlay similar to a weighted summation technique (Eastman, *et al.*, 1995). The key to advancing from deterministic overlays is to incorporate MCA with GIS.

Key aspects in this area include selecting appropriate MCA techniques and the integration of

represented in GIS. A more advanced method involves using MCA software to capture criteria valuations and inputting those weightings as attributes of spatial features which are

programming. Jankowski (1995) describes two methods of integrating MCA and GIS. The most widely used is a loose coupling strategy in which GIS and MCA software are linked via an

apparently seamless integration (Jankowski and Richard, 1994; Carver, 1991; Janssen and Rietveld, 1990). An extension of the loose coupling strategy is tight coupling strategy in which

both

Various MCA techniques have been used with GIS and applications are dominated by siting

Diamond and Wright (1988) who suggested the combination of multi-objective programming with rule-based models and GIS for land use planning. More recent applications include:

agricultural land use change (Janssen and Rietveld, 1990);
ideal point analysis (IPA), hierarchical optimisation and concordance discordance analysis to model suitable locations for radioactive waste disposal (Carver, 1991);
compromise programming, similar to IPA, implemented through external MCA software for criteria valuation and GIS map algebra for manipulation (Pereira and Duckstein, 1993);
multiple accounts framework for forestry/wildlife conflicts (Brown *et al.*.
- pipeline route selection (Jankowski and Richard, 1994).

A system to support problem solving in the public domain must have a flexible design to accommodate the complexity and unstructured nature and variations in the context and

in this capacity as it almost always assumes a single model to investigate a single structured problem (Gould, 1989). GIS cannot directly accommodate conflicting objectives, variations in

variations in selecting and using information.

The second perspective on the development of decision support capabilities of GIS which

spatial analogue of Decision Support Systems (DSS) developed in operational research and management science for business problems. DSS were developed in response to inadequacies

advancements in computing technology which made it possible to place computing power in the hands of decision-makers (Konsynski , 1992; Er, 1988; Keen, 1987). Similar analogies can be made with respect to GIS in the development of SDSS (van der Muellen, 1992; Fedra and

problems for which there is no straightforward means of solution.

A concise and consistent definition of SDSS is not evident from the literature. In general, SDSS are computer systems which combine a database management system, spatial and non-spatial analytical models, and graphical and tabular reporting integrated with human-expert knowledge within a decision-making framework accessed by a user-friendly interface to provide alternative solutions to a decision problem (Carver, 1991; Densham, 1991; Honey *et al.* 1991). Although many of these components can be said to be found in GIS, SDSS are differentiated from GIS by the addition of advanced spatial analysis capabilities (e.g. MCA), the expertise of the decision-makers and a suitable user interface (Carver, 1991). SDSS emphasise the iterative and interactive generation and evaluation of alternatives rather than traditional optimising choice processes (Densham and Armstrong, 1987).

The most prominent area of research in the field of SDSS is the internal integration of analytical and modeling techniques such as rule-based models, MCA and simulation and optimisation models emphasised as the key to computer-based decision support (Strapp and Keller, 1996b; Fedra, 1995; Fotheringham, 1991; Abel *et al.*, 1992; Clarke, 1990; Kessell, 1990). Other areas include:

- customised user interfaces with real-time dialogue (Fedra, 1995);
- incorporation of expert and decision-makers' knowledge and skills (Armstrong *et al.*, 1990), and
- SDSS architecture (Abel *et al.*, 1992; Armstrong *et al.*, 1986).

There are an increasing number of applications described as SDSS. However, it is questionable whether they satisfy the description of SDSS defined earlier. Again, it depends on one's definition of 'decision support'. This issue presents the opportunity for a thorough review of SDSS applications using GIS. Development of SDSS have been led by applications in locational planning, specifically spatial reorganisation of education services (Honey *et al.*, 1991). Power and Saarenmaa (1995) describe an application based on an object-oriented structure for tree pest management. SDSS were also applied to land consolidation (Strapp and Keller, 1996a). Environmental management is also an increasing area of SDSS development (Negahban *et al.*, 1995). However, Fedra (1995) notes that "Success stories of actual [SDSS] use in the debate and policy-making process, such as water resource management, are somewhat more rare, in particular at the societal rather than commercial end of the spectrum of possible applications".

Collaborative Spatial Decision-Making

Decision support capabilities of GIS primarily have been designed for single users usually experienced in GIS. As was discussed earlier in Section , there is a trend for public planning and resource management to be undertaken by multi-party task forces involving non-scientist decision-makers and in some cases the general public. In many cases, decision-makers do not have access or cannot operate GIS due to inadequate experience or interface complexity. While the GIS technology is advancing, this has not been matched by an ability to integrate non-GIS specialists and their expectations (Green, 1995; Raal *et al.*, 1995). A new generation of GIS-based DSS are being developed to meet these shortcomings, namely collaborative spatial decision-making systems (CSDMS). As with SDSS, the development of CSDMS has taken the lead from Group Decision Support Systems (GDSS) developed primarily for business applications (Gray *et al.*, 1992; Nunamaker *et al.*, 1991; DeSanctis and Gallupe, 1988) whose basic aim is to

converge the divergent views of decision-makers towards an agreeable solution of a specific problem.

There are several examples of the use of CSDMS varying on the interaction of decision-makers with the system and the level of analytical complexity. Perhaps the earliest was *Strabo* developed in 1983 by Luscombe and Poiker (1983). Using a modified Delphi methodology, a panel of expert decision-makers used thematic and confidence maps to reach an agreement. Confidence maps allowed decision-makers to graphically see the certainty and relative merits of alternatives. The heuristic approach allowed them to modify their responses in light of others and the general group consensus position. A similar approach was used by Lesser *et al.* (1991) to reduce conflict among intra-governmental interest groups over alternative land use development strategies. A GDSS has been designed for oil and hazardous chemical oil spill response in which, like coastal planning, numerous issues must be considered by a group of experts in order to arrive at a decision on appropriate action (Gould, 1989). Godschalk *et al.* (1992) developed a teaching tool which enables participants to apply their decision criteria by specifying weights in an overlay analysis. Statistics are generated for each scenario thus produced, and evaluated and negotiated by the different stakeholder groups. Shiffer (1993) describes a multi-media system incorporating video and sound which allows users to evaluate impacts of a planned transportation project. CITIES (Collaborative Information Technologies for Integrated Environmental Solutions), an interactive decision analysis system using GIS as a display component, was implemented for a hypothetical application of wetlands construction (Schnase *et al.*, 1994). The system uses Live Board, a large screen, pen-based interactive computer screen and decision analysis software to construct goal-oriented decision trees to evaluate alternative scenarios.

Despite these examples, Armstrong (1994) argues that research, particularly with respect to interactive capabilities and avoiding the GIS 'bottle-necks' is required before CSDMS are viable within an actual decision-making setting. Armstrong and Densham (1994) warn of some potential problems of using CSDMS:

- 'chaotic jumble of participants' making it difficult to distill the essential characteristics of alternative solutions from multi-criteria methods;
- decision-makers may not be cognisant of implications of GIS analysis on data quality;
- access to computers due to cost and availability, and problems of the physical transfer of data and technology to decision-makers, due to storage capacity and software license restrictions;
- system requirements needed to run GIS;
- conceptual access barrier of GIS technology;
- manipulation of the map display by an individual to influence an outcome of the group;
- mode of operation of the system can influence an individual's autonomy and group collaboration; and
- dominance of more technically-experienced participants and timidity of those less experienced.

Research directions have been suggested to address some of these issues and to synthesise the research agenda of CSDMS along two veins: technical issues relating to tool development, and applications issues relating to tool use (Densham *et al.*, 1995; Armstrong, 1994).

Research directions of tool development include:

- spatially-related functions and analysis required to support CSDMS;
- customisation to individuals' needs and to a group with wide range of users;
- representation of users' interests such that they can be compared;
- use of hypermedia and shared drawing space to aggregate opinion and plans, and to best represent commonalities and differences among alternatives;
- group modeling analysis such as multi-criteria techniques which allow decision-makers to see the implications of changing model components and to trace changes of scenario development;
- group consensus building tools for conflict resolution and stakeholder input; and
- sensitivity analysis in which consequences of weights are made transparent to the users to determine the effect of changing a single component of a complex model.

Research directions of tool use include:

- roles of participants and facilitator;
- the effect of CSDMS on the decision-making process;
- forms of interaction between users and the system;
- evaluation of the effectiveness of CSDMS; and
- establishment of a protocol of interaction among users.

Data Quality

Any decision support technology, whether it is GIS, SDSS or CSDMS, is fundamentally an information system, and decisions are consequently based on the information contained therein. Of paramount importance is the need to assess the suitability of a data set to an intended application, and to assess the uncertainty of a decision based on the uncertainty of the information. Unfortunately, the drive to build GIS applications often neglects the fabric of the data. Too often effort is focused on 'feeding the beast' and minimal regard to 'what the beast is being fed'. With graphic display and ease of data manipulation poor data quality data can be easily disguised. The data quality is influenced by the inherent errors. Any errors in individual data layers are compounded by the integration of various data sources.

Issues of data quality are present in all data regardless of whether GIS is used. However, there are characteristics of GIS which increase the need for attention. These characteristics include an effective infinite precision implying an accuracy equal to the level of storage and display precision, something rarely encountered (Goodchild and Gopal, 1989). Whereas on paper maps, the user infers accuracy levels from the scale of the map, GIS boast the capability to store scaleless data, allowing users to zoom in with the touch of a button. The fundamental link between scale and accuracy, therefore, is weakened (Chrisman, 1989). One of the main strengths of GIS is the ability to integrate and overlay numerous independent data layers. However, this procedure implies homogeneity of a data base instead of recognising the inherent heterogeneity (Chrisman, 1995), and data layers so combined may not be suitable for combination due to differences in scale, data quality, or data collection methodology (Openshaw, 1989). In addition, Openshaw (1989) notes that data manipulation using GIS is carried out in a 'black box' in which vendors are reluctant to release details of processing algorithms. Analysis easily can be carried out at the touch of a button not requiring users to be experts in geographic data or spatial analysis. With advances in communication technology, it also has become cheaper and more efficient to move data through networks, thereby separating

data collectors, data analysts and decision-makers such that knowledge gained by one group regarding the quality of the data is often not relayed with the data due to lack of metadata.

graphics, colours and definitive boundaries of GIS. These characteristics have led researchers to claim that these GIS capabilities are a false lure which can lead decision-makers astray (Abler,

The issue of data quality is not new to GIS and is considered one of the main areas requiring attention (Goodchild, 1992). Initial research focused on identifying sources of error, usually

(Aronoff, 1993; Goodchild and Gopal, 1989; Burrough, 1987). Considerable research attention is focused on developing mathematical models of error propagation using Monte Carlo

expert systems (Veregin, 1994; Heuvelink and Burrough, 1993; Pullar and Beard, 1990; Dutton, 1989, Fisher, 1989). While mathematically appealing, it is argued that error propagation models

applications and require in-depth knowledge of the history of the data as well as mathematical engineering. Secondly, they are based on the assumption that errors are due to imprecision in

uncertainty (Veregin, 1989). Finally, error propagation models often yield extremely low confidence levels in processed data. Nevertheless, reporting of single accuracy measurement or

analysis has been used as an alternative to spatial error propagation (Stoms *et al.*,

More recently a broader approach has been taken in investigating data quality in GIS. This has been spurred by a need for a more pragmatic approach to data quality (Basta, 1990) and

the reliability and usefulness of data (Chrisman, 1995; Aronoff, 1993; Chrisman, 1991; LeBlanc *et al.*,
relevant evaluations of data quality as on the provider to provide that information. In this capacity, data quality is defined as 'fitness for use', defined by data characteristics or metadata,

metadata: positional accuracy; attribute accuracy; logical consistency; completeness; and lineage. These components are usually regarded as a starting point supplemented by other

to the relationship between a measurement and the reality which it purports to represent, and precision as referring to the degree of detail in the reporting of a measurement, or in the

both spatial and attribute coverage. Time is particularly important in the marine environment where processes and organisms are subject to cycles ranging from hours to years. If an

lifespan of the various data by noting currency. Lineage is often referred to as 'audit trails'. It accounts for the history of the data from collection to last access for edit, manipulation or

data into the final format (Canessa and Keller, 1993). Of these metatdata components, lineage has received the most attention (Brown, 1995; Lanter, 1994) and current research focuses on

There are various methods of reporting data quality assessment. These include compliance test results, single numerical accuracy index, raw accuracy assessment statistics and textual description of errors (Veregin, 1993). Composite indices of data quality such as an overall rating scheme (Blyth *et al.*, 1993) or percentage effectiveness compared to the ideal (Smith and Piggott, 1987) have been used. Data quality also can be reported as a surface of uncertainty using multivariate kriging (Davies *et al.*, 1995; Kielland *et al.*, 1993). Metadata can also be stored as information items in printed form (Nicholson, 1994, pers. com.) or digital form as in the Vector Product Form (VPF) of the Digital Chart of the World (Chrisman, 1995).

The challenge of reporting data quality, particularly with respect to decision-making, is a trade-off between simplicity and flexibility (Chrisman, 1995). A single scale or index of data quality will not serve all potential users. Alternatively, the metadata approach has the potential of generating considerable information for users and decision-makers to digest in deciding the suitability and reliability of data for a specific application. It is important to allow standards to vary as a function of the application context (Veregin, 1993).

Veregin (1993) also points out three data scales at which data quality can be assessed. Most used is the layer-based approach in which data quality reporting is assumed to be representative for the entire layer. A feature-based approach assesses data quality for each feature in a data base which can result in redundancy and too much information. An alternative between the two is a domain-specific approach is which data quality assessment is disaggregated over the spatial, temporal or thematic domain into discrete classes.

The issue of data quality has not been ignored in the marine GIS community. Hydrographic agencies have taken the lead in data quality assessments due to the implications to safety and navigation of erroneous or inappropriate data (Davies *et al.*, 1995; Nicholson, 1994, pers. com.; Kielland *et al.*, 1993). In addition to the standard metadata components, the assessment for the Canadian Hydrographic Survey (CHS) also includes a vertical coverage component to supplement horizontal spatial and attribute coverage (Nicholson, 1994, pers. com.).

2.6 COASTAL AND MARINE GIS

The intent of this research is to coalesce the fields of multiple-use coastal management with GIS-based decision support tools. Research into coastal GIS is in its infancy and has proliferated in recent years as exemplified by the two annotated bibliographies, GIS software workbook exercises, a dedicated international conference, and the increasing pervasiveness of GIS in the coastal management literature (Furness, 1995; Rickman and Miller, 1995; Bartlett, 1993; St. Martin, 1993). Research has focused on design factors and suitability of GIS to represent the marine environment, applications of GIS to coastal and marine projects and most recently on the development of coastal decision support systems.

Design and Suitability

Throughout its evolution coastal GIS have been subject to the assumption that a tool originally developed for the terrestrial environment automatically can be transposed to the marine environment. Despite the spatial and temporal differences between terrestrial and marine environment, there has been surprisingly scant research on technical requirements of coastal GIS.

borrowing but not readily transposing from terrestrially-designed GIS. The synthesis of a technical framework for marine GIS centres on the difficulty in representing the coastal

various scales (Keller *et al.*

Resolution of these issues has focused on data models to spatially represent the coastline and temporality. Most commonly, the coastal zone is represented as a singular linear entity (Fricker

linear model augmented with dynamic segmentation can capture the fractal dimensionality and multiple attributes of the coastline (McCall, 1995). However, the linear model does not

recursive hierarchical tessellation has been suggested to tackle the multiple scales and resolution challenge (Bartlett 1992; Bartlett, 1990).

Jones (1995) argues that the biggest technical challenge for the development of GIS in ICM is

appropriate data model incorporating both third- and fourth-dimensional models. These have been addressed in a limited capacity and with few exceptions outside the marine discipline *et al.*, 1993; Stepchuk, 1989 in Webber ., 1990).

By focusing on space, GIS essentially maintain time constant. Temporal variability can be

in the coast these have the potential of creating huge volumes of data which will encumber the use of GIS. More recent research has focused on a more elegant solution of real-time GIS. In the

chart display and information systems (ECDIS). Nevertheless, it is likely that a truly spatio-temporal GIS is still a thing of the future (Langran, 1995).

Perhaps the reason for the general lack of treatment of technical issues of coastal GIS, is that institutional challenges to coastal management seem to dwarf technical ones in comparison

GIS for coastal management has forged ahead as institutional challenges are met. The applications have been inventory-driven as coastal managers take advantage of GIS' ability to

exchange, all promoting the integrative requirements of ICM. These benefits a best summed up by Jones (1995: 166): "A key feature of coastal management is integration, a feature which also

perspective of interactions between uses, links between land and marine processes and distribution of impacts; producing graphic and tabular output for improved visualisation for

Garcia and Kapetsky, 1991; Bartlett, 1990).

These benefits have resulted in a wide range of applications in the coastal environment. It is

Jones (1995) and Rickman and Miller (1995) for such reviews. However, attention will be drawn to those applications which relate to management of coastal uses, the examples of which primarily focus on single-sector issues such as:

- fisheries habitat management (Harper *et al.*, 1990);
- site suitability for fish farming and mussel culture (Krieger and Mulsow, 1990);
- marine aggregate extraction (Evans and Giddings, 1991; Jeffries-Harris and Selwood, 1991);
- natural resource coastal tourism (ARA Consulting, 1992);
- oil spill response contingency planning (Howes, 1993);
- port management (Webber *et al.*, 1990);
- permitting (Chinnis and Joyner, 1995); and
- socio-economic analysis (Wong *et al.*, 1991).

Despite the widespread understanding of the benefits of GIS for ICM and broader multi-sectoral strategic planning, actual examples of such use are scarce (Ricketts, 1992; Berris, 1991; Townend, 1991; Clark, 1990).

One final note with regard to coastal GIS applications. Although examples abound, as with ICM techniques, details on methodology are usually lacking in published reports, leaving it up to the reader to infer methodology from the context of functions of the GIS software used (Paw, 1995). Paw (1995: 131) further argues that "a large number of the so-called 'application studies' are cartographic and/or simple overlay, search and retrieval, so that full utility (*i.e.* to include geographic modeling) is underrated". This leaves research susceptible to continuous re-invention of the wheel with respect to both ICM and coastal GIS methodology.

Coastal Decision Support Systems

Most recently several Coastal DSS are under development or in prototype stages although not all necessarily use GIS as a platform. Some emphasise the information and mapping/graphic communication capabilities for decision-makers in a user-friendly desktop platform (Raal *et al.*, 1995; Grose, 1994). Others have developed Coastal SDSS which allow users to compare pre-defined development scenarios on pre-established evaluation criteria (Raal *et al.*, 1995; COSMO, 1993). These offer limited interactive capabilities beyond displaying and querying data. More advanced Coastal DSS integrate numerous commercially available software such as GIS, hydrodynamic modelling, desktop mapping packaged within a customised user interface allowing more interactive modelling (Percy, 1994; Post *et al.*, 1994; Ji *et al.*, 1993; Murphy and Fruggle, 1989). Many are packaged within a modular format facilitating the addition of new analytical modules as the need arises. Most of these applications are for aquatic ecosystem management such as watershed, estuaries, wetlands and rivers. Although the expert system developed by Murphy and Fruggle (1989) is intended to support preliminary environmental assessment of water related resort development in the coastal zone. Most are designed for expert decision-makers although the emphasis, for example, of the Annapolis Watershed Aquatic Resource Enquirer (AWARE) in Nova Scotia is intended for community-based management (Percy, 1994).

2.7 SUMMARY

decision support tool, within Coastal SDSS. Each of these fields in itself is a broad topic, and merging the relevant literature can pose a challenging task. The preceding review has

that contribute towards the development of Coastal SDSS for multiple-use management. illustrates the main points raised in the literature.

demands for finite resources and space at the coast. The accepted approach to manage these demands is Integrated Coastal Management (ICM). Four elements of ICM are addressed,

systems. The development of coastal information systems brings ICM directly in the GIS field. The development of Coastal GIS has addressed the suitability of conventional terrestrial-based

coast. While these technical issues are being addressed numerous Coastal GIS application have been developed.

inventory and communication. Related to the use of GIS for inventory is the need to be aware of data quality issues which can easily be disguised in GIS. Beyond inventory capabilities, GIS

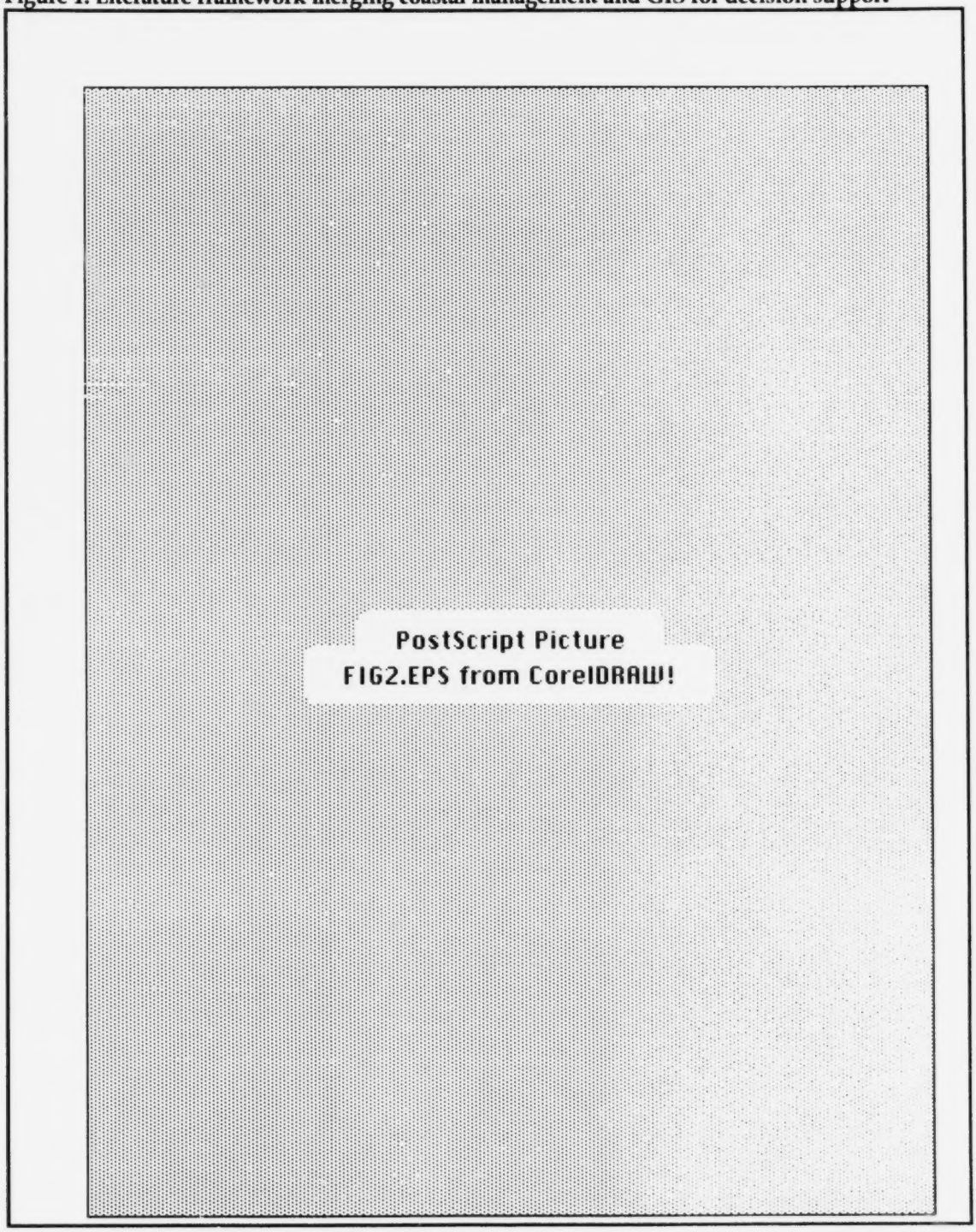
analytical techniques, GIS analytical functionality has been augmented with more advanced techniques such as multi-criteria analysis. This makes it an attractive tool for spatial planning,

Decision Support Systems (SDSS). Most recently a new element of decision-making has been introduced to SDSS, namely decision-making groups. This development has given rise to a

Figure 1 shows that these two streams can merge together toward a Coastal SDSS. In addition, it shows that there are four linkages which bind the merger:

- the fundamental requirement of a coastal inventory and the fundamental function of GIS as a spatial information system;
- the establishment of multi-party task forces in ICM and development of group-based SDSS;
- strategies; and
- these techniques in GIS.

Figure 1: Literature framework merging coastal management and GIS for decision support



3.0 RESEARCH DESIGN

3.1 RESEARCH FRAMEWORK

This section describes the methods undertaken to accomplish the research objectives discussed in Section One. The research questions identified in Section 1.3 were addressed through six stages:

(1) Identify coastal management decision-making process.
(2) Identify analytical functionality requirements.
(3) Identify data requirements.
(4) Develop pilot Coastal SDSS.
(5) Implement pilot Coastal SDSS.
(6) Evaluate and refine Coastal SDSS specifications.

The methods undertaken to accomplish the research objectives of the study are summarised as follows. Firstly, generic decision-making, analytical and data criteria of Coastal SDSS were investigated through a literature review, questionnaire surveys and interviews (Steps 1-3 in Figure 2). This investigation led to the development of a pilot Coastal SDSS by customisation of a commercial GIS (Step 4). Thereafter, the pilot Coastal SDSS was implemented in a case study through two workshops (Step 5). Finally, the researcher and workshop participants evaluated the effectiveness of some of the key aspects of the pilot Coastal SDSS to assist in coastal planning and management (Step 6).

3.2 QUESTIONNAIRE SURVEY

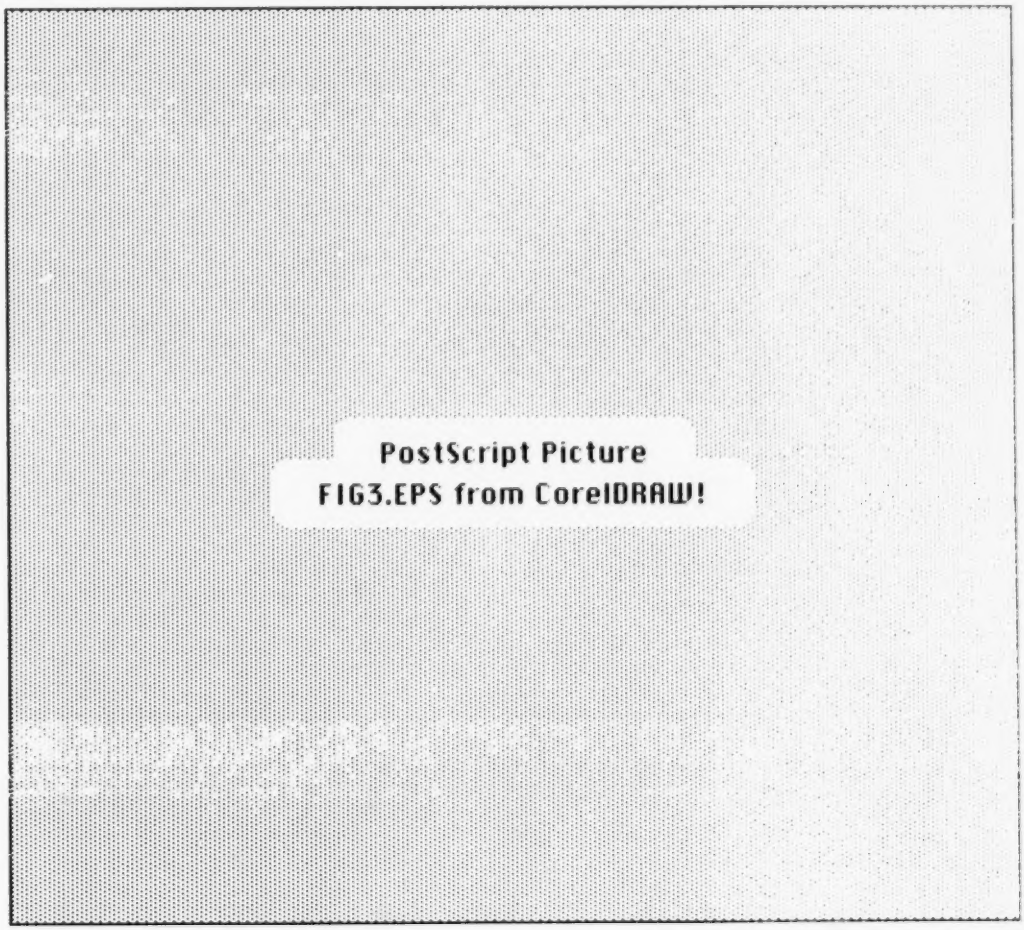
The need to consult and involve decision-makers in the development of GIS decision support technology has been emphasised by several researchers (Raal *et al.*, 1995; Basta, 1990). The objective of the questionnaire survey in this study was to answer this call and ascertain from likely users of Coastal SDSS details of the coastal management decision-making process. This included analytical and inventory components, and the attitudes and expectations of respondents to using a GIS-based Coastal SDSS. A two-phased mailed questionnaire was undertaken.

Phase I

The objective of the first questionnaire was to gain general information on coastal management initiatives and decision-makers' knowledge, experience and expectations of GIS. The questionnaire was structured in three parts all comprising open-ended questions. Part A requested descriptions of coastal management initiatives in which respondents had participated. Part B asked about respondents' specific experiences with GIS including their perceived strengths and weaknesses of GIS with respect to maintaining and managing an inventory of coastal data, manipulating and analysing coastal data, and supporting multiple-use decision-making. Part C sought information on the professional background of respondents and their organisation's mandate. One hundred and fifty questionnaires were mailed to coastal decision-makers in April 1994. Forty-four questionnaires were returned completed (29% response rate).

Participants were selected from the literature, conference proceedings, coastal management programs and personal contacts. The emphasis was to seek coastal decision-makers rather than GIS experts *per se*. Forty-three percent of the respondents came from British Columbia, with the remainder from eastern Canada, the United States, Europe and South Africa. Organisations represented were primarily provincial or state (36%), and federal governments (23%). Other organisations represented comprised regional governments, independent commissions, universities and consulting firms. Most respondents were at that time engaged in planning and regulatory work (41%) or research primarily focused on providing scientific information (32%). Respondents worked in a wide range of fields related to coastal management with primary emphasis on ecology/environment (36%), and comprehensive resource and land use planning (31%). In addition, sectors such as aquaculture, conservation, tourism, navigation, geology and geomatics were represented. GIS experience ranged from none (20%) to post-secondary education (14%).

Figure 2: Research design and methods



Phase II

The purpose of the second questionnaire was to follow-up on some of the themes emerging

data quality, and coastal decision support systems. The questionnaire was structured in four parts. Part A sought information on specific techniques and methods used to explore and

respondents to rate their agreement on a five-point scale with various statements pertaining to the importance of data quality for decision-making, responsibility for evaluating data quality,

importance of various metadata criteria. Part C presented respondents with a matrix of decision-making tasks and participant groups to which cost and time budget estimates were

implementation.

Phase II was administered by mail in March 1995 to 83 coastal decision-makers comprising all

original Phase I group. Twenty-four participants returned completed questionnaires (29% response rate) of which 14 had completed Phase I.

geographical range, organisational representation, responsibilities and professional disciplines.

Questionnaire Analysis

makers with as few boundaries placed on their responses as possible. This was accomplished primarily with open-ended questions. Open-ended questions encourage expression of ideas

be relevant. However, open-ended questions do have the disadvantage that their responses are more difficult to summarise and report than tightly-controlled questions. Open-ended

commonalities, both of which were encountered in the results of this research. Open-ended questions therefore, were evaluated using the technique of content analysis as suggested by

reported and summarised using descriptive statistics. It was not thought appropriate to go beyond descriptive statistics to more rigorous statistical analysis to verify hypotheses. This is

given the low frequency of responses observed in some of the categories identified through content analysis. The absence of more rigorous confirmatory statistics is also justified given

hypotheses. However, it is recognised that a larger sample size would have enabled testing some valuable hypotheses such as differences in responses from people of different

national experiences.

3.3

To gain experiential insight into the use of GIS in decision-making, interviews were conducted with individuals who had participated in a multiple-stakeholder decision-making process in which GIS was used. The decision-making process selected was the Commission on Resources and Environment (CORE) established in 1992 by the British Columbia government as an independent regional planning commission mandated to coordinate consensus-based strategic resource management throughout the province. One of the first regions initiated was Vancouver Island (VI). The process began in 1992, with a decision-making group comprising representatives from fourteen resource sectors. Their objective was to develop a comprehensive land use plan for Vancouver Island. Throughout the process GIS was used and operated by a Technical Working Group (TWG). The TWG inputted data and undertook analysis to generate alternative land use plans. The results of the analysis were presented as reports and hardcopy maps to CORE participants during following meetings. A data browsing inventory and map display package was made available to participants in a room separate from the decision-making table to explore the available data and alternatives. The process terminated in 1993, without reaching consensus. A Vancouver Island land use plan was ultimately proposed to government by the CORE Commissioner, derived from two diverse alternatives emanating from the process (CORE, 1994).

Between August and September 1995, in-person unstructured interviews were conducted with five members of the VI CORE process, each lasting on average about an hour. An attempt was made to contact all the representatives and those finally interviewed were chosen by their availability and proximity to the researcher. The objective of the interviews was to determine the extent to which GIS had been used in the decision-making process and the participants' evaluation of its use.

3.4 PILOT IMPLEMENTATION

The results from the surveys and interviews contributed to the formulation of design specifications of Coastal SDSS. Experimental research which combines information, science, technology and decision-making is also an important source of information and one that is lacking in coastal management research (Basta, 1990). A pilot implementation of a coastal SDSS, therefore, was a critical component of this research. It served to evaluate the effectiveness of a GIS-based decision support system in multiple-use coastal management. In so doing, the preliminary design specifications developed from the questionnaires and the interviews were augmented and refined.

One of the factors which influence the quality of system evaluation is the realism of the experimental design (Adelman and Donnell, 1986). Most examples of DSS system evaluation are conducted with university student subjects (Gardner *et al.*, 1993). This approach provides an adequate supply of subjects for reproducible iterations and allows a measure of control of the experimental design. However, using students limits the experimental realism of a study, as students have neither the experience which matches the complex tasks of multiple-use coastal management, nor do they represent the population for which a Coastal SDSS is intended (Beauclair, 1989). Evaluating the Coastal SDSS in the field, on the one hand, is generally more complicated to organise, is less controllable and predictable, limits the number of replications, and makes it more difficult to develop appropriate application scenarios. On the other hand, field evaluation with subjects who have a stake in the issue and a prior history of interaction increases the degree to which the subjects believe in and take the task seriously

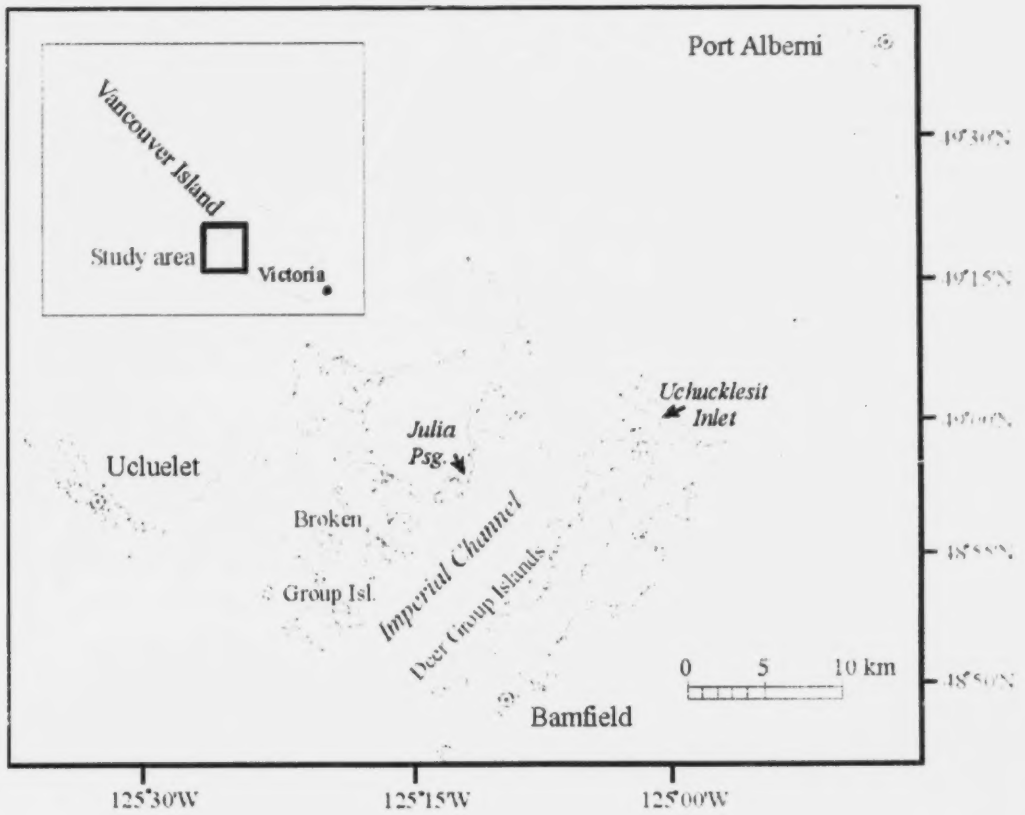
(Sambamurthy and Chin, 1994). Hence, it was deemed preferable to evaluate the pilot system within a realistic case study.

It is important to emphasise that the primary purpose of the pilot study was to evaluate the Coastal SDSS and to contribute towards the development of design specifications. Secondary to this purpose is the contribution to problem solving of the decision issue at hand. This emphasis on experimental objectives over decision objectives is reflected in the results reported. The contributions to the problem solving are reported only as they pertain to Coastal SDSS design specifications.

Barkley Sound Case Study

The case study area chosen was Barkley Sound on the west coast of Vancouver Island (Figure 3). It is an approximately 770 km^2 body of water open to the Pacific Ocean to the south-west. A 47 km long inlet flows into it from the north-east. Barkley Sound is characterised by open waters, fjords and numerous island groups.

Figure 3: Case study area Barkley Sound, Vancouver Island, British Columbia



Like many coastal areas around the world, Barkley Sound faces increased residential, industrial, resource and recreational development. On the fringes of Barkley Sound are three communities populated by approximately 21,500 people (1993 B.C. Ministry of Government Services, Central Statistics Branch estimates). Alberni-Clayoquot Regional District, within which Barkley Sound lies, is presently experiencing significant population increases and accompanying residential construction (Ferguson *et al.*, 1994). Industrial activities, including a pulp mill and port facilities, are concentrated at Port Alberni.

The economy of Barkley Sound is resource based, primarily forestry and to a lesser extent fisheries, both commercial and recreational. Although current forest harvesting is set back from the shoreline, marine-based forestry activities include log storage, sorting and transportation to the pulp mill at Port Alberni. Barkley Sound supports all five Pacific salmon species although primarily chinook and sockeye are the foundation of the local fishery. Commercial landings of these species averaged $3.3 million per year between 1982 and 1991 (Ferguson *et al.*, 1994). It is also important to note that in recent years the number of salmon caught in the recreational fishery has exceeded those caught in the commercial fishery. Also, aboriginal fisheries are increasing in the area. In addition to salmon, herring, geoducks, horse and intertidal clams, shrimp, red sea urchins, prawns, gooseneck barnacles and squid are also harvested. Commercial aquaculture of salmon, oysters, clams and mussels is an important economic activity in Barkey Sound. Aquaculture production contributed almost $2 million in 1991. Fluctuations in the industry reduced that figure to approximately $1 million in 1992 (Ferguson *et al.*, 1994).

Barkley Sound is renowned for its scenic features and recreational opportunities centred on the Broken Group Island of the Pacific Rim National Park Reserve. Recreational pursuits in Barkley Sound are dominated by recreational fishing although other popular activities include:

- boating - sailing, cruising, kayaking and canoeing;
- camping, hiking, beach activities;
- wildlife viewing, especially whale watching;
- scuba diving;
- shellfish harvesting;
- day sightseeing; and
- access to the West Coast Trail, Pacific Rim National Park.

Commercial recreational developments in Barkley Sound include wilderness and fishing lodges, campgrounds, marinas, and guiding and support services. Recreational activity in Barkley Sound has increased by approximately 70% in recent years as evidenced by recreational fishing effort, campground occupancy, boat launching, day berthing, passenger trips on local passenger/freight vessels, visitation to the Broken Group, and recreational float cabins.

These development demands combined with Barkley Sound's unique environmental setting intensify pressures of allocating foreshore for private and public uses. To address these pressures, a multiple government agency committee was formed in 1992 to develop a planning strategy for Barkley Sound. A non-binding cooperative planning strategy was developed "to guide the long-term use, development and management of the lands and resources of Barkley

Sound and Alberni Inlet" (Ferguson *et al.*, 1994: iii). In addition to specifying goals, objectives, priorities and policies the strategy also provided for zoning Barkley Sound into five designations, namely Marine Recreation Area, Aquaculture Priority Area, Community Development Area, Rural Development Area and Environmental Protection Area. Each designation is defined by permissible and conditional uses to guide the allocation of land and water uses in Barkley Sound.

The currency of multiple-use issues was a prominent reason for selected Barkley Sound as a case study. The second important reason was the availability of a comprehensive digital spatial database compiled for the Barkley Sound strategy. The vector database was compiled in a graphics package by consultants who assimilated over 50 data layers from over 20 agencies participating in the Barkley Sound Strategy process and from published reports. In order to create a functional GIS database, the data required considerable work in geo-referencing, creating topology and ensuring the internal consistency of the data. Once the study area was chosen, there were two approaches for developing a specific multiple-use scenario which could have been pursued. These reflect the two approaches to coastal management, namely area-based and issue-based.

An area-based approach involves determining the most appropriate use of a region which balances the relative interests. This approach was followed in developing the Barkley Sound strategy and little would be gained by repeating the exercise. Using an area-based approach for this research would require a very broad and complex case study. It would be difficult to both encapsulate such a case study within the time limitations and conform to the experimental objective of this study. Instead of considering the whole of Barkley Sound, a region of Barkley Sound could be evaluated with an area-based approach. Potential regions were investigated by this researcher and were deemed to be geographically too small to develop area-based management. An issue-based approach, on the other hand, focuses on a particular use or sector of the environment for which a management regime is developed with consideration of other users and the environment as a whole. For the purpose of this study, an issue-based approach represents a more manageable and concise scenario to meet the objectives of the pilot implementation.

One outstanding issue emanating from the Barkley Sound Planning Strategy is the distribution, rights and regulations surrounding float cabins. Float cabins are small structures constructed on rafts, logs or other flotation devices and anchored in sheltered bays with boomsticks or by wharves tying the rafts to the shoreline. Float cabins have proliferated over the last fifty years, a situation resulting from little or no regulation. There are currently approximately 100 cabins dispersed throughout the Sound with several areas of congregations. The issues arising from their presence include competition for space, environmental impact and regulation (Table 1).

Solutions suggested in the Barkley Sound Strategy to deal with these issues included removing all float cabins, clustering cabins into groups of three to five, establishing communities of approximately twenty cabins or maintaining the *status quo*. A Float Cabin Sub-Committee was formed to devise recommendations for the regulation of float cabins. The multiple users, stakeholder interests and potential conflicts involved, and the possible options for float cabin development make this a challenging task. It was decided to implement the Coastal SDSS to the float cabin issue as a tool to explore alternative configurations of float cabin distributions

while considering implications for other users and the environment. The implementation would be carried out in two workshops.

Table 1: Multiple use and management issues surrounding float cabins in Barkley Sound

ISSUE	DESCRIPTION
Float cabin tenure	Float cabin owners are requesting secure tenure with appropriate lease fees and conditions and recognition as a legitimate recreational use.
Fairness in the allocation of foreshore use	Many other residents are requesting equal opportunities to use the foreshore for private recreational use.
Alienation of recreational foreshore	Float cabins and adjacent log booms sometimes occupy prime anchorages and recreation sites, and restrict public access to the shore.
Environmental effects	Concerns exist about the discharge of sewage and grey water and about the water pollution potential and uncertainties at various sites. These concerns were particularly raised with respect to the impact on existing and potential aquaculture and the related need for sustained good water quality.
Commercial lodges	Several float cabins are being used for small-scale commercial businesses, by-passing commercial lease regulations.
Governance	Any float cabin regulation regime implemented and enforced will have associated costs which will most likely have to borne by the float cabin users.

Although the issue of locating float communities involves multiple interests, users and resources, it is inherently a single-use planning issue. This factor potentially provides some limitations on the broader application of this research to a complex multi-use strategic issue. These potential consequences are further discussed in Section 8.

System Development

The pilot Coastal SDSS was developed using ArcInfo™ by ESRI. Arc Macro Language (AML) was used to develop a customised menu-driven interface and to program analytical functionality. Technical details on the Coastal SDSS are found in Sections 5 and 6.

Pre-trial

Two pre-trials were conducted to evaluate the presentation and format of the Barkley Sound workshops, and to test the analytical methodology developed. Students of a third year resource management course at the Department of Geography, University of Victoria, were chosen as subjects. The students were in the third month of the course and were well-versed in issues surrounding resource management and consensus-based processes, although not coastal

management *per se*. The pre-trial was run with each of two sections of the course with 40-50 students in each section.

Students were introduced to consensus-based resource management decision-making by the course instructor. Afterwards, this researcher introduced them to the overall research and explained the exercise objectives. The students were divided into eight stakeholder groups representing the actual stakeholder participants to be present at the workshops. Each group was given a card describing its role and perspective on the issue of float cabins in Barkley Sound. All students assembled at a round table for short presentations by each group on its concerns and interests on the issue. A streamlined version of the exercises planned for the Barkley Sound workshops was run using ESRI's ArcView™ (operated by this researcher). ArcView™ was connected to an overhead projector through which maps could be displayed to the whole class, thereby facilitating information exchange and discussion. Not more than five students in each class section had previous experience with GIS. The pre-trial lasted for three hours with each class and concluded with a discussion on the use of GIS and the general methodology applied.

The pre-trial provided suggestions for conducting the Barkley Sound workshops, particularly to allow each participant to state their interests at the onset of the meeting, and to include sufficient time for participants to explore the digital data as a group to frame the decision problem. In addition, the methodology for combining data layers was altered mathematically to allow for the contingencies which arose in the pre-trial.

Workshops

Experimental realism was an important goal in the implementation design. It would have been ideal to implement and evaluate a Coastal SDSS throughout the entire course of a decision process. However, due to time constraints and the schedule of the Barkley Sound Float Cabin Sub-Committee which met only once a month, this was not a viable option. Therefore, as much as possible, the decision process had to be represented within the confines of two sub-committee meetings at which the researcher was present as a participant observer, and two one-day workshops. This made available less time than was desired, particularly with respect to structuring the decision problem and exposing individuals to the methodology and GIS capabilities.

The *research objective* of the workshops was to evaluate the role and effectiveness of GIS to support multiple-use coastal management in an interactive group setting using Barkley Sound as a case study area. The *decision objective* of the workshops was to explore alternatives for the location of float cabins in Barkley Sound taking into account multiple users and stakeholder interests. The Barkley Sound Float Cabin Sub-Committee did not contain a broad range of coastal users pertinent to this study. Therefore, for the workshops, participants of the sub-committee were supplemented with three other user groups. Members of the Barkley Sound Float Cabin Sub-Committee (of the Barkley Sound Strategy Committee) comprised:

(1) Alberni-Clayoquot Regional District,
(2) Port Alberni Harbour Commission;
(3) British Columbia Ministry of Lands;
(4) Regional directors of planning boards representing Barkley Sound communities; and

(5) Barkley Sound Float Cabin Owners' Association and Julia Passage Rate Payers' Association.

Additional non-committee representatives comprised:

(6) First Nations from the Nuu-chah-nulth Tribal Council,
(7) Barkley Sound Shellfish Growers' Association; and
(8) Recreational boaters.

Other organisations and representatives who could have participated in the workshops include different government agencies such as the Coast Guard, Ministry of Health and Ministry of Environment, and other community participants such as kayakers, sports fishermen and lodge owners. In consideration of the core Float Cabin Sub-committee and in the interest of efficiency in terms of the experimental objectives it was decided to limit the participants of the workshops.

Although field testing limits the number of iterations, holding two separate workshops (held on consecutive days) allows one to compare results between the workshops and to examine the reliability of the evaluation. Eight interest groups were present at each workshop represented by different individuals with the exception of First Nations in which the same representative was present at both workshops. Because there were three planning board regional directors on the Barkley Sound Float Cabin Sub-Committee, two were present at the first workshop bringing the total number of participants to nine compared to eight participants in the second workshop. Nine of the sixteen participants were members of the Float Cabin Sub-Committee. The participants varied in their experience with Barkley Sound, group decision-making and GIS as shown in Table 2. It is interesting to note that four particpants from Workshop #1 and one participant from Workshop #2 attended a demonstration of ArcView™ and the Barkley Sound data as members of the Float Cabin Sub-committee, although they replied 'No' to the question on GIS experience in the pre-workshop questionnaire. This perhaps indicates the perceived expertise required before being comfortable and confident with GIS.

Participants were seated in a U-shaped table. A computer connected to an overhead projector was located at the front of the room for graphic display from ArcView™. A second computer with ArcInfo™ used to run the pilot Coastal SDSS was located to the side of the main table. Both computers were operated by an experienced GIS analyst. The proceedings of the workshops were video taped and an independent observer was present to supplement records and observations. The workshops were facilitated by this researcher. At the workshops, participants were given a list of data available in the database. In addition, they were given a paper map of Barkley Sound for notes.

Following an explanation of the objectives and format of the workshops, participants introduced themselves and presented their interests, concerns and objectives with regard to float cabins in Barkley Sound. The initial stage of the workshops involved setting the scope of the issue during which the GIS data were available for display and query. Again, due to time constraints, it was necessary to conduct some analysis prior to the workshops, the results of which were presented for discussion. The workshops concluded with an interactive discussion to explore multiple-use implications of various float cabin community alternatives.

Table 2: Profile of workshop participants (# participants)

	Workshop #1 (n=9)	Workshop #2 (n=8)
Familiarity with issue Participated in Barkley Sound Strategy or Float Cabin Sub-committee	6 (67%)	5 (63%)
Experience with group decision making Member of Barkley Sound or other group decision-making process	7 (78%)	6 (75%)
Experience with GIS Previously seen demonstration or first hand experience with GIS	1 (11%)	4 (50%)

System Evaluation

In addition to experimental realism, a second set of factors which influence the quality of system evaluation are the measures and procedures taken to assess effectiveness (Adelman and Donnell, 1986). There is considerable literature on evaluating the effectiveness of group decision support systems (GDSS) focusing on the benefits of computerised *vs.* manual support, embedded decision structures, and group interaction and dynamics. A discussion of evaluation of GDSS is presented in Appendix B. The evaluation procedure used in this exercise combines subjective participant judgement, non-participant observation, participant observation and objective measurement to gather information on various effectiveness variables (Table 3). A pre-meeting questionnaire was administered to the participants one week prior to the workshops.

This questionnaire focused on gathering:

- user variables including their experience in group decision processes, familiarity with Barkley Sound issues, and experience with GIS;
- perception of the decision problem and potential for resolution; and
- pre-meeting consensus.

A post-meeting questionnaire was administered immediately following each workshop. Fourteen of the sixteen participants completed the questionnaire. This questionnaire focused on process variables, namely:

- perceptions of the decision problem and resolution;
- attitudes towards the use of Coastal SDSS; and
- assessment of Coastal SDSS capabilities.

Table 3: System evaluation for Barkley Sound workshops

	Stakeholder Participants		Non-participant Observers	
	Pre-meeting[1]	Post-meeting[2]	Subjective[3]	Objective[4]
USER VARIABLES:				
Experience in group decision-making	v			
Familiarity with Barkley Sound issues	v			
Experience with GIS	v			
PROCESS VARIABLES:				
Perception of decision problem	v		v	
Pre-meeting consensus	v	v		
Range of alternatives	v	v	v	
Group dynamics			v	
Proclivity to participate			v	v
Extensiveness of use				v
Interaction with GIS			v	v
NON-PROCESS VARIABLES:				
System capabilities		v	v	
CONTROL VARIABLES:				
Group size				
Stakeholder group				
System orientation				
System capabilities				

1 Questionnaire and non-participant observation by the researcher during to Float Cabin Sub-Committee meetings;

2 Questionnaire and group discussion;

3 Observation;

4 Video recording

Re-examination of the participants' perceptions of the decision problem and potential for resolution, and their attitudes towards the use of Coastal SDSS enables one to evaluate the changes induced by the workshops. Additional process variables and participant evaluation was gained from a group discussion which took place after the questionnaires were completed.

Two non-participant observers present throughout the workshops and the researcher (in a facilitating role) provided comments on:

- general flow of proceedings;
- group dynamics;
- participation and behaviour of participants; and
- effectiveness of the pilot Coastal SDSS to meet participant demands at the workshops.

These were supplemented with objective measurements acquired from the video on length of time for each exercise, extent of use, proclivity to participate and extensiveness of use.

3.5 WRITING METHODOLOGY

To recap, there are four sources of information gathered during this research: two questionnaires, interviews and the Barkley Sound workshops. The results from each could be presented in turn. However, there are numerous themes that recur throughout all information sources. Therefore, the integrity of discussion is enhanced by reporting the results not according to information source, but rather according to these themes. In keeping with the four topic areas of the research framework (Section 1.3), the results and observations from each of these information sources will be woven together into a comprehensive compilation according to decision-making (Section 4), analysis (Section 5), data (Section 6), and implementation of a Coastal SDSS (Section 7). To maintain the flow of discussion , relevant but supplementary material is included in the Appendices. This writing methodology is susceptible to an apparently disjointed presentation of results and may be difficult for the reader at times. However, it is anticipated that overall it will contribute to a better understanding of a Coastal SDSS.

3.6 SUMMARY

This section presented the research design including the type and sequence of tasks, methods of information gathering, the case study used to implement the Coastal SDSS, and methods of system evaluation. The research design is encapsulated in showing the six tasks and methods pursued to accomplish the research objectives. A variety of data gathering methods was pursued comprising a two-phased questionnaire survey of coastal managers and interviews with participants from a group decision-making process. A coastal management case study using float cabin development in Barkley Sound, Vancouver Island, formed an integral part of the research design. It permitted participant observation of a multi-stakeholder coastal management process and the evaluation of the pilot Coastal SDSS in a realistic setting through two workshops. Table 3 summarises the methods and variables of system evaluation. This used a combination of pre- and post-meeting questionnaires completed by participants, a post-meeting discussion, non-participant observations, and objective observations from a video of the proceedings. A combination of user variables, process variables and non-process variables were evaluated in addition to establishing control variables between the two workshops. This section also set the scene for reporting the results in the following sections according to decision-making (Section 4), analysis (Section 5), data (Section 6), and implementation of a Coastal SDSS (Section 7).

4.0 DECISION MAKING

4.1 INTRODUCTION

Coastal spatial decision support systems (Coastal SDSS) necessarily operate within decision-making processes. In order to determine where and how Coastal SDSS might function within those processes, it is important to characterise the manner in which multiple-use coastal management decisions are made (Section 4.2), and ascertain both the decision-makers' expectations of using GIS as a decision support tool and the potential impact of Coastal SDSS on the decision-making process (Section 4.3).

4.2 COASTAL DECISION MAKING PROCESS

The decision-making process comprises the substance of and structure through which coastal management is conducted. This section focuses on four components of the decision-making process: the issues and interests around which the process evolves; the steps and tasks taken to address these issues; critical factors which influence the outcome; and the decision-making participants involved.

Characteristics of Coastal Management Initiatives

Respondents of the Phase I Questionnaire described 44 different coastal management initiatives and projects involving multiple interests. They were asked to "specify the geographical area, scale of problem and nature of multiple-use conflict". In addition, they could supplement their responses with relevant reports or papers. Although not intending to be a comprehensive account of coastal management, the information provided can be used to identify characteristics of coastal management such as the type of multiple-use interactions involved, management objectives addressed, multiple-use interests represented, and geographic scale.

Multiple use interactions

As previously discussed in Section 2.2, the interaction among users on the coast can have different roots, such as environmental impact, aesthetic or amenity impact, resource competition, space competition, and opposing values or philosophies. Of the 44 initiatives described, most (61%) involved some degree of environmental impact interaction, for example the impact of dredging on fish habitat and resulting fisheries, pollution from point sources such as sewage outfalls, and pollution from non-point sources such as agriculture. Spatial competition, such as between aquaculture and boat anchorages, were factors in fifty percent of the initiatives. Twenty-three percent referred to conflicts of values or philosophies, most typified by general opposition between conservationists and developers. Direct competition for resources, for example, between commercial and sport fisheries, characterised seven percent of the initiatives. These results reflect the multiplicity of coastal interactions. The initiatives were not confined to one type of interaction but often included a combination of interaction types.

Management objective

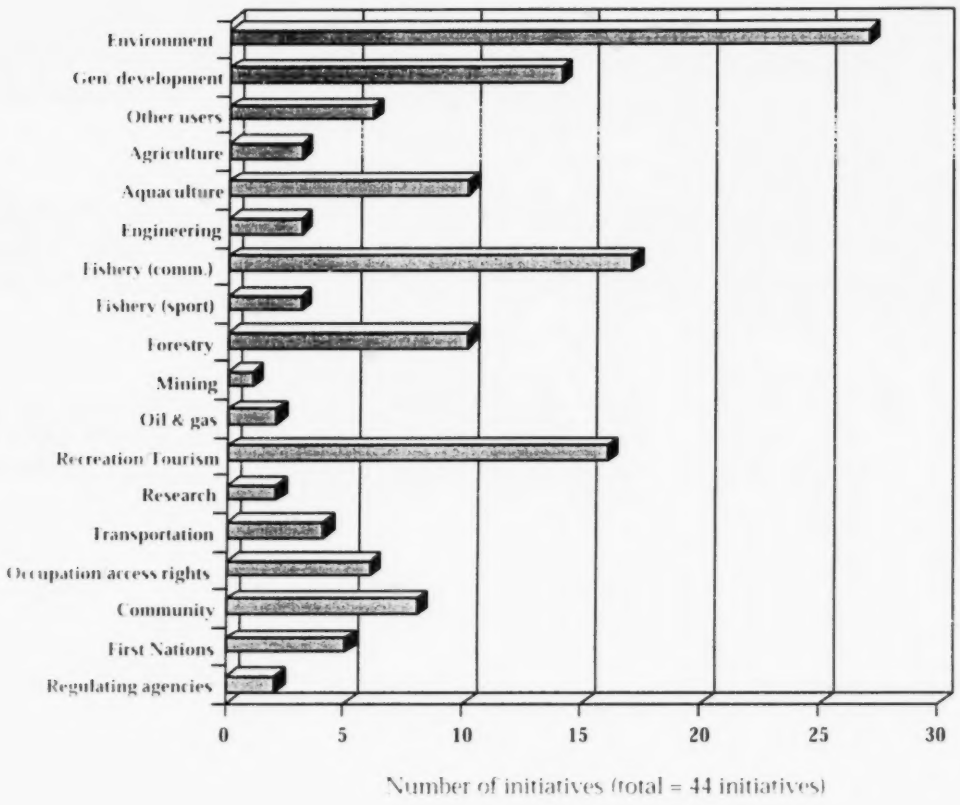
Approaches to addressing the multiple-use interactions were classified into five management objectives, namely land and/or marine use strategy; development and activity siting; conservation and protection; environmental impact assessment and contingency planning; and

resource management. With the information provided it was possible to classify 35 of the 44 initiatives described. The remaining nine did not provide sufficient detail for classification. One initiative was classified with two objectives. Conservation and protection, use strategy, and activity siting were equally considered the most predominant management objective. Although, it should be noted that the category of conservation and protection might be over-represented by the response from one conservancy council. The establishment of conservation or protected areas included parks, sanctuaries and reserves. While in some cases the establishment of protected areas was aimed at resolving multiple-use interactions, in other cases they were in fact the source of conflict. Multiple-use interests were also taken into account through single sector development or activity siting, such as waste disposal, forestry, recreation, aquaculture, tourism and urban development. In these cases, the management focus is on one sector having implications on other interests which might be taken into account through a government referral system or more extensive public processes. Marine and/or land use strategy, most notably zoning plans, which take an integrated multi-sectoral approach, was the management objective for slightly fewer initiatives than those focusing on conservation or single sector activities. Although most multiple-use interactions among users were caused by environmental impact, this majority was not reflected in the EIA/contingency planning management objective.

Multiple use interests

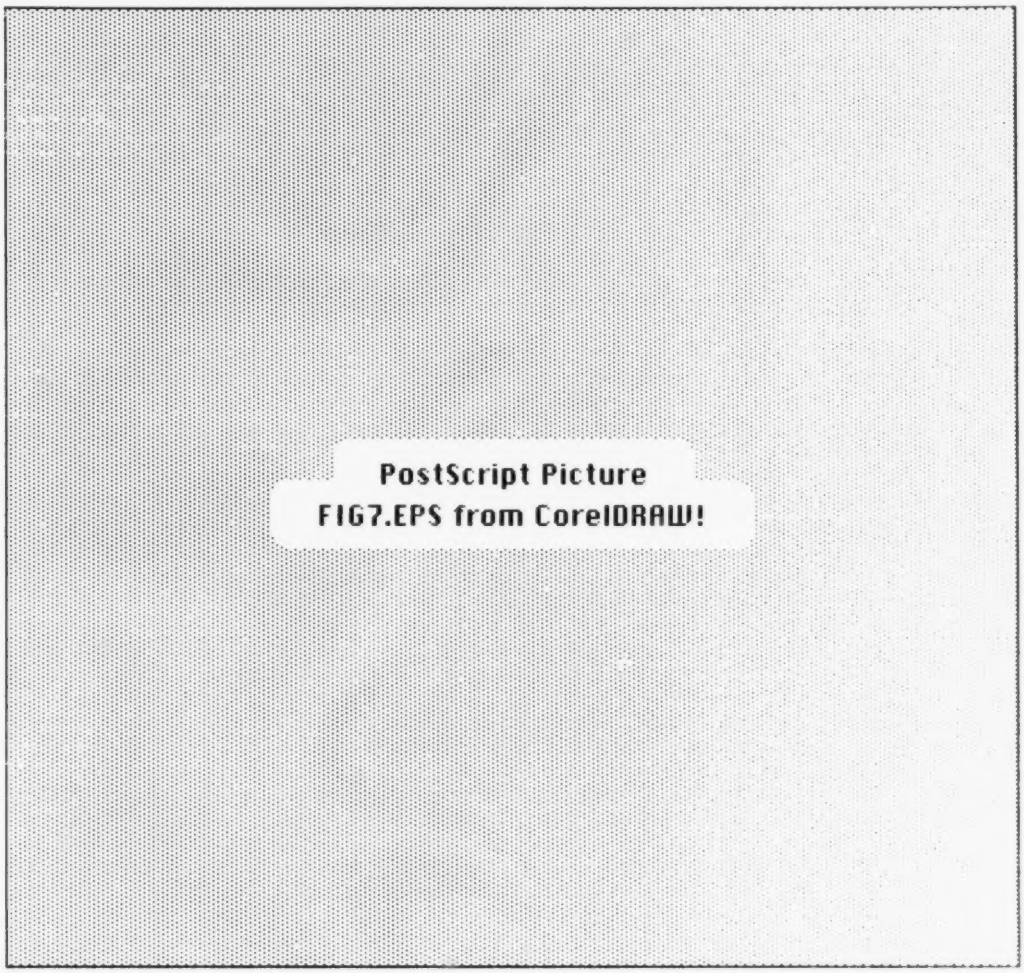
Eighteen different interests were identified in the 44 initiatives described in Phase I (Figure 4). Environmental interests, primarily fish habitat and wetlands protection, were the most common, present in 61% of initiatives. General development pressures such as commercial development, urbanisation and population growth were present in 32% of initiatives. Of sector-specific interests, commercial fishery and recreation/tourism were the most common, represented in 39% and 36% of initiatives.

Figure 4: Coastal interests (Phase I)



Fifty-three percent of the initiatives described involved only two interests. However, 30% of these were described generally as environmental and development interests indicating the possibility that more specific interests may in fact be represented. Almost 20% of the initiatives involved five or more interests. Figure 5 depicts a pairwise comparison of the interests described. In addition to general environment and development pressure, other interest pairs commonly associated include: environment and recreation/tourism; commercial fishery and recreation/tourism; environment and commercial fishery; environment and forestry; and recreation/tourism and local community.

Figure 5: Multiple interest matrix (Phase I)


PostScript Picture
FIG7.EPS from CorelDRAW!

Scale

The initiatives were generally evenly divided between regional initiatives (57%) and local initiatives (43%). Regional initiatives involved large estuaries, island groups, and areas incorporating more than one jurisdiction of local government such as provincial or state initiatives. Local initiatives involved reefs, bays and communities. Table 4 explores the relationship between scale and the management objectives of the initiatives. Conservation/preservation objectives appear to be associated with regional initiatives. Development/activity siting appear to be associated with local initiatives. However, the latter should be viewed with caution, again due to the responses from a single conservancy council.

Table 4: Relationship between management objective and scale (Phase I)

	Scale	
Management objective	**Regional** (n=21[1])	**Local** (n=15[1])
Use strategy	5 (24%)	4 (27%)
Development/activity siting	2 (9%)	7 (47%)
Conservation/preservation	8 (38%)	2 (13%)
EIA/contingency planning	5 (24%)	2 (13%)
Resource management	1 (5%)	0

[1] These exclude the 9 initiatives for which there was insufficient detail to ascribe a management objective. One local initiative was ascribed to two management objectives.

Process Steps and Tasks

Questionnaire participants were asked to "describe the organisation of participants and list the steps or planning strategies involved in the decision-making process". There was extreme variability and generality in the responses and they can be summarised as follows. Twenty-five percent of the processes described could be identified as consensus-based, characterised by multi-stakeholder participatory decision-making. Half of the processes were government-led involving public and interest group consultation without direct stakeholder participation in the decision-making process. The remainder of the processes involved minimal participation by stakeholders and interests, and can be characterised instead as agency-led initiatives with some involving government referrals. Further details on decision-making participants are presented below.

There is no apparent prescription of set-ordered tasks for coastal management decision processes. The numerous specific tasks identified in Phase I can be consolidated into ten main categories progressing from Problem Definition to Monitoring (Table 5). Although the tasks are presented in a linear manner, as one respondent noted "there should be no assumption that there are discrete steps involved in the decision process"; in reality, there may be no clear cut

separation. Some tasks may be addressed simultaneously, backtracked or omitted altogether depending on the issues being addressed and the process established.

Table 5: Coastal management tasks (Phase I)

MAIN TASK	SUB-TASK
Define Problem	
Establish Process	• establish steering committee • identify stakeholder interests and participation • terms of reference • set goals/targets/objectives • procedural definition
Collect Data	• identify data needs • agency data contribution • field surveys • ecological, geographical, sociological research • identify present use
Analyse/Assess	• values • site surveys • assess conflict areas • forecast demands • develop methodology to resolve conflict • scientific formulation • environmental impact assessment
Synthesise	• problem solving • identify solutions/options • analyse alternatives • round table discussion • negotiations/mediation/facilitation • consensus/agreement • production of map output • formulation of draft plan strategy • recommendations
Review Draft	• government referrals • public review • seminars • open houses • public conferences
Revise Strategy	
Adopt Strategy	
Implement Strategy	
Monitor Implementation	

Critical Factors

•

Sixty-one percent of respondents noted that the coastal management process in which they were involved was successful in reaching satisfactory coastal use decisions. The primary reasons cited were:

- co-operation among the participants especially different levels of government and upfront commitment to complete the process by reaching a mutually satisfactory outcome;
- availability of information, particularly accurate data shared by all participants;
- an ecological context or goals to the process; and
- stakeholder involvement particularly in a consultative capacity.

Other factors mentioned included:

- effective communication of data and results particularly in graphic format;
- the presence of a clear conflicts;
- establishment and adherence to a clear process and decision criteria;
- compliance among participants; and
- innovation in problem solving.

The eight factors (14 responses) cited to influence the negative outcome of a process can be broadly divided into four categories: non-technical; technical; procedural; and legal. The most oft-cited factor was political motivations of participants as well as the local political climate. Other non-technical factors included control of information by participants during the process, international pressure, and public misunderstanding. Two respondents noted lack of technical merit in basing decisions as an instrumental factor. Lack of evaluative criteria was another technical issue cited. Procedural issues comprise a widespread mandate to consider all interests and the absence of significant issues on the negotiation table. Legal issues such as jurisdictional conflict and lawsuits were cited by three respondents.

Decision-Making Participants

Given the increasing emphasis placed on multi-party task forces, community management and stakeholder participation, the identification of the specific decision-makers was sought. A total of twenty-four different specific coastal management case studies which included participants were described in Phase I. Provincial and state governments head the list of coastal decision-makers involved in 80% of the initiatives, of which 92% of these agencies were working in concert with others. The importance of multi-party task forces is further reinforced in the description of success factors for coastal management presented earlier, in which co-operation and commitment among the participants was the most common answer reported in 38% of cases described. Furthermore, one respondent noted that within government, the best results are achieved when the process is inter-agency driven rather than lead agency.

Consideration for stakeholder participation in the decision-making process was raised several times in Phase I. Stakeholders, including business, industry and the general public, were involved to varying degrees in 54% of the initiatives described. In addition, the identification of stakeholder interests and public involvement was cited as one of the most important success factors.

With respect to the Barkley Sound process, the Strategy was developed by a Committee comprising four federal agencies, eight provincial agencies, two regional agencies and a First Nations tribal council. The Float Cabin Sub-Committee, charged with implementing a specific component of the strategy, has a more community-based membership and is comprised of regional agencies, local representatives and direct stakeholders -- the float cabin owners' association. Other relevant stakeholders were not involved directly in the decision-making process. The overall sentiment of the residents and local planning agencies was for local responsibility over Barkley Sound. Although a provincial ministry is one of the lead agencies of the Sub-Committee and is responsible for overall policy, this ministry generally defers local issues to the regional agency.

Participants of Phase II were asked to assign the tasks listed to any participant group in the matrix presented or to any additional participant group they wished to supplement (Table 6). The table shows a clear 'division of labour' between data management tasks assigned predominantly to technical support staff as well as to research scientists and consultants, and 'decision-making' tasks assigned predominantly to the planning authority. Establishing the decision framework in terms of criteria and solution procedures were placed firmly in the hands of the planning authority. Stakeholder and public involvement were primarily assigned to querying the inventory and generating and evaluating alternatives.

Table 6: Predominant participant group assigned to each task (Phase II)

	Participant Group					
Task	Political Body	Planning Authority	Stake-holders	Research Scientists	Technical Support	Consult-ants
Id. data requirements		v		v		
Data availability					v	
Collect data				v	v	
Compile inventory					v	v
Maintain inventory					v	
Query inventory		v	v		v	
Id. decision criteria		v				
Solution procedures		v				
'What-if' exploration		v				
Generate alternatives		v	v			
Evaluate alternatives		v	v			
Make decision	v					

4.3 GIS AND COASTAL DECISION MAKING

In the preceding section, the generic characteristics of coastal management which contribute to the decision-making environment were explored. This section adds the GIS factor to this environment. This sequence is in accordance with the research philosophy raised in Section 1.3; address the problem first, then investigate a tool, in this case GIS. Five areas are addressed with respect to GIS and coastal decision-making: the use of GIS in initiatives reported, the broader role of GIS, the impact of GIS on decision-making, and perceived strengths and weaknesses of GIS pertaining to coastal decision-making.

Use of GIS

Phase I questionnaire respondents were asked whether a computer decision support system or GIS assisted in the conflict resolution process in which they participated and described earlier, and if so, in what capacity and for what purpose was such a system used. GIS was used for both inventory/mapping and analysis in seven of the 44 coastal management initiatives described in Phase I. Of the remaining initiatives in which GIS was not used, 15% reported that GIS was in development, and 30% reported that other computer systems were used, primarily mapping software but also databases and marine circulation models. Seven percent noted that while GIS was not used directly by the decision-makers as a group, various participating agencies used GIS and contributed results to the group. In these cases, the management body then focused on data sharing among the contributing agencies rather than combined implementation.

In only one case, the Vancouver Island CORE process, was the use of GIS known to have occurred, to some degree, in a group decision-making setting. Prior to meetings, a Technical Working Group (TWG) conducted analyses to generate and evaluate alternative planning scenarios, the results of which were presented to the group at the decision-making table. During the meetings a data browsing and display GIS package was maintained and operated in a separate room by the TWG. Participants were given time to display and query data through an operator, but the participants interviewed noted there was often a lack of time and opportunity to do so. On several occasions the GIS was used to display from an overhead projector, and more extensively for the generation and dissemination of hardcopy output.

Role of GIS

The broader role of GIS was investigated by asking what, if any role GIS could play in making decisions about multiple use on the coast. The most common roles identified by Phase I respondents for GIS in coastal management decision-making were for the storage of an integrated inventory, and for communication and display. In the former role, it was advocated that GIS accommodates the compilation into a common database of the wide range of data needs typical of multi-disciplinary initiatives such as coastal management. In addition several respondents noted that GIS facilitates data sharing, standardisation and co-ordination, thereby avoiding duplication in data collection effort. The emphasis on communication and display is placed on the production of easily understood output, particularly for a wide-ranging audience from "professional scientists to environmental planners and politicians to various public interest groups". Other roles identified include 'what-if' exploration and evaluation of alternative planning scenarios, and spatial identification of conflicting or competing interests.

Of those who identified roles (32), 28% noted the expectation that GIS would improve the efficiency of decision-making through flexibility and speed in providing analysis and results to the extent that GIS allows for a "dynamic decision-making process".

Despite these expectations of the uses of GIS, several respondents noted words of caution limiting the role of GIS in coastal decision-making:

- "GIS will be *only* one tool";
- "Many factors that go into the final decision are non-spatial";
- "GIS could be used to *influence* decision-making, but the decision would still be political"; and
- "GIS provides the background information but the actual decision-making about multiple use is still made by the agencies after technical overview and public discussion".

These impressions were echoed by some of the participants of the Barkley Sound workshops who commented that "The final decision is of course human, as local information, knowledge and intuition cannot be included in a software package". A stronger view was expressed by one participant, "I know where the float cabins should go and no amount of computers or data are going to tell me otherwise". Workshop participants and questionnaire respondents emphasised that although GIS is a useful tool, there are other factors outside of GIS to consider, such as socio-economic implications.

The prospective role of GIS was explored more specifically in Phase II of the questionnaire with respect to the incorporation of a GIS-based decision support system within a group decision-making setting. Three options of system incorporation based on formats supported in Group Decision Support Systems (GDSS) (Nunamaker *et al.*, 1991) were presented in the questionnaire:

- *Interactive* — Used directly and interactively by the decision-makers at the decision-making table for display, query, analysis and as a tool to seek consensus.
- *Chauffeured* — Used at the decision-making table by technical staff for display, query, analysis and as a tool to seek consensus upon the direction of decision-makers.
- *Background* — Used as a background tool by decision-makers and/or technical staff, the results of which are brought to the decision-making table.

In the first option, each decision-maker has access to a terminal for display and input which is networked to a central processing unit. One could argue whether the last option is a true GDSS since the decision-makers do not themselves interact or even see the system, but rather see the results brought to the table.

Respondents were asked to choose the scenario they would prefer to be involved in as decision-makers, noting advantages and suggestions as to the option chosen. The preferred option (50%) of Phase II respondents was *Background* in which there is least involvement between the Coastal SDSS and the decision-makers. This format was preferred because information would be provided without clutter and seduction of GIS at the table. It would place GIS as a tool and not as a decision-making process and was seen to be a more time efficient and effective use of the technology than the other two options, given the prospective technical expertise of decision-makers. However, a drawback of this approach, evidenced in the

VI CORE process with the establishment of technical committees, is that "technical committees can only be populated by those participants for whom the technology is accessible, the industry thereby putting other groups at a disadvantage". Suggested requirements include a protocol to ask and frame questions, and a single operator within the decision-making group.

Twenty-seven percent of respondents preferred a chauffeured-style implementation. They felt that with the availability of a system operator it would be more efficient than the *Interactive* format and the technical staff would be on hand for explanation of constraints and limitations. It would also encourage collaboration between decision-makers and technicians, and provide decision-makers with a better understanding of the data than would either of the other two options. There would be less possibility of seduction, the output would be readily available for decision-makers and would encourage involvement for group participation. According to the respondents, implementing this option would require easily understood output or screen display, and application-specific training.

An *Interactive* implementation, which represents the most direct and dynamic involvement of decision-makers, was preferred by 23% of respondents. It was noted that this option would provide a transparent box for decision-makers, and the flexibility and immediacy of display. This option was determined to be the most inclusive and participatory of the implementation scenarios, and would provide equal access and a level playing field. On the other hand, one respondent noted that an interactive system could in fact create an unbalanced playing field giving an advantage to those 'techno-philic' decision-makers and a disadvantage to the 'techno-phobic'. Suggested requirements for implementing an interactive system include training at various levels, the flexibility and methodology to update, and a mediator to manage the flow of information.

A chauffeured system was chosen for evaluation at the Barkley Sound workshops. During post-workshop discussion it was felt by the participants that this option provided an effective balance between 'hands-off' and interactive. If decision-makers were given direct use of the system, it was felt that the system could be used by those more technically proficient to detract or divert attention from the decision-making process. As one workshop participant succinctly commented, "Let us concentrate on the issues, let somebody else use it". One participant commented that the presence of numerous terminals around the decision-making table may also impose an underlying physical barrier to dialogue and communication among the participants.

Impact of GIS on Decision Making

It is anticipated that the introduction of a computer system, in any format, will inevitably impact the decision-making process in some capacity. The use of GIS in both the VI CORE process and the Barkley Sound workshops can be explored to elucidate this impact.

In the VI CORE process, GIS was described as 'overwhelming', 'defunct', superfluous and 'ineffectual' for several reasons. Firstly, the analysis, particularly to develop and evaluate alternative land use plans, was conducted away from the participants at the decision-making table. Participants were therefore "less aware of how the analysis was actually conducted" and perhaps less likely to place confidence in it. However, from another viewpoint, "There was too much going on in terms of political jockeying to be engaged in analysis at the table". Secondly,

although participants were given extensive theoretical and philosophical background on consensus-building and negotiation, they were "not given adequate analytical and problem-solving skills and techniques". Again, this can contribute to lack of preparedness in the use of GIS for decision support, particularly analytical problem-solving. These problems were not attributed to GIS, but rather "The failing of the [GIS] system with respect to effectiveness, was a result of the [decision-making] process". In this case despite having been endowed with data, technology and a technical working group, ultimately these can be undermined and 'ineffectualised' by the decision-making process. This was attributed to the large number of people around the decision-making table, the management of information communication, and the ability of the mediator to incorporate GIS into the process.

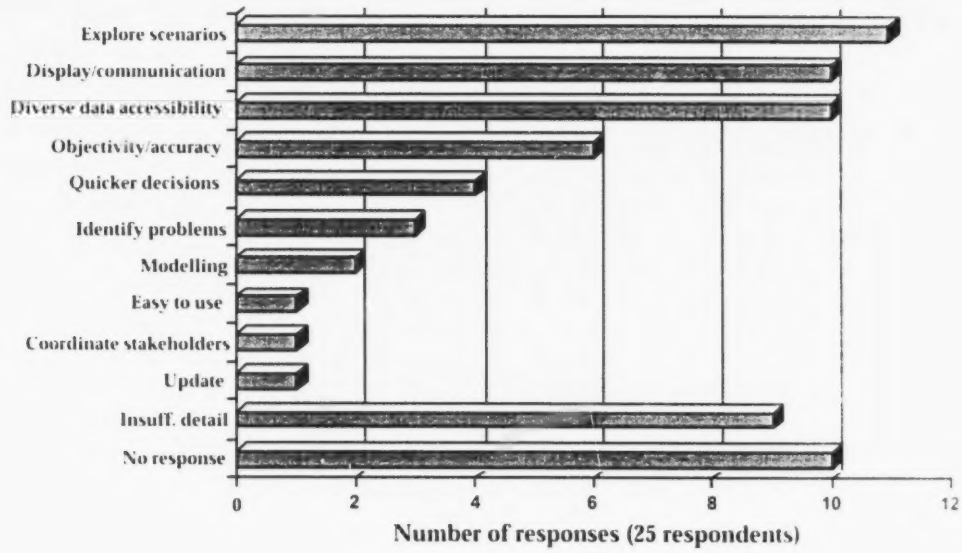
With respect to the Barkley Sound workshops, it is difficult to separate the impacts of the group interaction, particularly given that the workshops brought together stakeholders who previously had not met, from the impact of GIS in the decision-making process. Regarding the decision objective, the workshops did not change the minds of any of the participants regarding the appropriateness of float cabins in Barkley Sound. The key contribution to the decision-making process identified by participants was in facilitating discussion and directing issues to pursue. This was particularly credited to the eyes-front display of the projection system which allowed the whole group to inspect the information and focus on particular areas or issues. The result is that the workshops in general and the use of GIS in particular served to widen the participants' views on factors and interests to be considered in locating or restricting float cabins. In addition, participants were able to acquire more detail on specific sites with *a priori* consideration of float cabin communities. One participant noted that the workshop revealed that there may not be adequate room to accommodate the existing number of float cabins without impact to other users or the environment and attributed this insight to the visual display and exploration of users and constraints. Perhaps the most notable testament to the impact of GIS was made by one workshop participant who, when asked whether GIS could be used in the continued process, replied "Now that we've seen it, we cannot *not* use it".

Strengths of GIS

In addition to the role and impact of GIS in coastal decision-making just discussed, there are specific strengths and weaknesses of GIS to consider. Respondents were asked, based on their experience, to comment on the perceived strengths and weaknesses of using existing GIS technology to support coastal management with respect to decision support and conflict resolution.

Although forty-three percent of respondents chose not to answer this question or did not provide sufficient detail in their responses, the strengths of GIS for decision-making identified by Phase I respondents are similar to the role of GIS discussed earlier. Mentioned foremost was the ability to explore and evaluate alternative planning scenarios (Figure 6). Again, display and communication capabilities such as the development of customised views of data, and inventory storage facilitating both data integration and accessibility were stressed. Several respondents noted that GIS lends a greater degree of objectivity and accuracy to the decision-making process. Decisions become based on data widely "perceived as objective" and precise. For example, " 'It's too close' becomes '2.7 miles away'".

Figure 6: Strengths of GIS to support coastal use decision-making (Phase I)



Similar responses were received from participants of the workshops. With respect to display and communication capabilities, the flexibility of data presentation, the visual overlay, and zooming in to allow the group to focus on a particular area were all highlighted by participants. In doing so, it served to stimulate discussion allowing participants to easily raise and address points to the group. The flexible display capabilities also facilitated the group to focus on areas and narrow down the problem while at the same time keep sight of the broader

picture. Several participants noted that the use of GIS provided more certainty and structure to the decision process. This was especially desirable to government representatives who had to substantiate to the public the decisions that resulted from the process. As with the questionnaire respondents and VI CORE representatives, workshop participants emphasised the ease with which 'what if scenarios' were explored and saw the potential to explore different alternatives.

Weaknesses of GIS

GIS are perceived to contribute to technologically or quantitatively driven processes to the exclusion of qualitative, non-spatial and human dimensions; "The 'data right' answer is not always the 'people right' answer". The resources required in terms of cost and time were identified as limiting the implementation of GIS for decision-making. In addition, GIS were seen to reside in the domain of technical experts which distances the managers and decision-makers from its use. GIS were also noted as being a seductive tool with unrealistic expectations as a panacea for coastal management, and encouraging a false sense of security in its users, leading to misguided use. The lack of data in terms of accessibility and quality was also found to limit its use. Many of these issues were re-iterated by the workshop participants who noted that the quality of the data, expertise required to operate GIS, and lack of knowledge of how GIS work, all impede their use for decision-making. In addition, while GIS may be useful in elucidating spatial conflict, such comparative analysis does not take into account the actual degree of conflict.

4.4 DISCUSSION AND SUMMARY

This section addressed the first component of Coastal SDSS, namely decision-making. Prior to exploring the potential application of Coastal SDSS to coastal decision-making, it was necessary to define the full extent of coastal management itself. This section started the definition by reporting on the issues addressed in coastal management and the process generally followed to resolve these issues. Once this foundation was established, the potential application of Coastal SDSS to coastal decision-making was pursued. The results reported focused on current uses of GIS in coastal management and their impact on decision-making processes. Following, attitudes of decision-makers towards the prospective role of GIS, and GIS' strengths and weaknesses were addressed.

Among the most common coastal issues raised throughout this investigation were environmental issues. These were raised with respect to environmental impact interaction which was the leading type of multiple-use interaction occurring in the initiatives described in the survey. Environmental interests were also predominant in the coastal interests identified. However, the focus on environmental issues was not reflected in the management objectives for the initiatives described. Resolution of multiple-use interactions was more commonly approached through protected areas, use strategies and activity siting than through environmental impact assessment.

Environmental issues represented broad coastal interests. Specific sector interests represented in the initiatives included recreation and tourism. Recreation and tourism were represented in more than a third of all initiatives described, second only to commercial fishery interests. This reflects the growth of recreation and tourism on the coast. These activities were more likely

than any other use-sector to interact with other interests, such as environmental, development, aquaculture, commercial fishery, forestry, transportation, communities, and First Nations.

In addition to defining the issues involved in coastal management, defining the process and tasks undertaken to resolve these issues was pursued. The coastal management process can be best described as the generation and evaluation of alternative strategies by a group of decision-makers. Within this general process, there were varied tasks identified. Responses were distilled to ten tasks comprising:

1. Define problem
2. Establish process
3. Collect data
4. Analyse/assess data
5. Synthesise results
6. Review draft
7. Revise strategy
8. Adopt strategy
9. Implement strategy
10. Monitor implementation

Respondents made it clear that these tasks do not represent a prescriptive process of ordered and discrete steps for coastal management. Some of these tasks may be addressed simultaneously, backtracked, or omitted altogether depending on the issues addressed and the process established. Furthermore, within these general tasks are a broad range of sub-tasks specific to each coastal management initiative. This has implications for the development of Coastal SDSS. Unlike business applications, for which DSS were originally designed, the coastal management decision process has been shown to be ill-defined and variable. This can lead to two avenues. First, the development of Coastal SDSS would need to focus on flexibility in order to accommodate the characteristics of coastal decision-making. Second, the development and implementation of Coastal SDSS themselves could prompt the coastal management process to become more defined.

Another key consideration in defining coastal management is the decision-makers. There is a general movement towards involving community stakeholders in the decision process. The results indicated that this movement has not translated into community participation in the initiatives. Coastal management is still led by government agencies, primarily at the provincial/state level. The results did emphasise, however, the range of stakeholder involvement considered appropriate. Involvement ranged from informing community members of decisions taken, through public consultation, to participatory decision-making. The term 'stakeholder' and 'community' is generously applied and is the focus of debate regarding definitions and degree of involvement. Jackson (1997) defines stakeholders as those individuals or groups who believe they have a stake in an issue. 'Stake' is further defined as that which may affect or be affected by an issue. It is possible that this inclusive definition can balloon into a large decision-making group. This has implications for coastal decision-making; the more relevant interests represented, the more comprehensive the outcome is likely to be. However, a large number of decision-makers can limit the efficiency of the process. A large and varied decision-making group can also increase the challenge of implementing a Coastal SDSS. There will be a wider range of expertise to accommodate, and more input to 'funnel' through a Coastal SDSS at the table.

Once the decision-making context of coastal management was established, the application of Coastal SDSS to coastal management was investigated. GIS are the foundation of Coastal SDSS. In addition, coastal managers are more familiar with GIS than they are likely to be with SDSS. Therefore, exploring the use of and attitudes towards GIS will yield information on the development and implementation of a Coastal SDSS.

Respondents maintained a guarded view of GIS within a decision-making process. This was due to the perceived expertise required to operate GIS and its potential seductive nature in terms of display and data quality. The expertise specifically represented a barrier for decision-makers to the implementation of Coastal SDSS directly by decision-makers. The barrier was exemplified by respondents' overwhelming choice of Coastal SDSS format -- as a background tool handled by technical staff away from the decision- making table. Questionnaire respondents and workshop participants emphasised that GIS should be considered one decision *support tool* and not a decision *making system*. Particularly Coastal SDSS should not 'slowly replace' the human element of decision-making.

All three target groups (questionnaire respondents, VI CORE representatives and workshop participants) emphasised the potential to use Coastal SDSS for generating and evaluating alternatives both analytically and interactively through the exploration of 'what-if' scenarios. However, the over-riding strength of GIS identified, and the one most familiar to decision-makers, was the ability to efficiently and flexibly display and query information.

The impact of implementing Coastal SDSS on the decision-making 'playing field' was also raised by all three target groups and must be considered in system design and implementation. Coastal SDSS could be used to exert influence on the process by directing its use according to the goals of those most familiar with the technology. Furthermore, Coastal SDSS could alienate those participants who do not have the technology in house or who are 'techno-phobic'.

Finally, once Coastal SDSS is at the table and accepted by decision-makers, the system must be effectively incorporated into the decision-making process. This relies on educating decision-makers on the functionality of the system and, perhaps more significant, the commitment and knowledge of the facilitator to direct the system's use.

This section focused on the decision-making component of Coastal SDSS. The following section reports on the second component -- analytical functionality.

5.0 ANALYSIS

5.1 INTRODUCTION

The operational goal of multiple-use management is the cross-sectoral allocation of space, time and resources which balances the various demands. This balance is most often manifested in a strategic plan. While it has been said that multiple-use management is starkly simple in concept (Clark, 1995), few will argue that the creation of a balanced strategic plan is simple to accomplish.

Developing appropriate and relevant analytical functions for a Coastal SDSS must be geared towards assisting coastal managers to derive a balanced strategic plan. Responding to this challenge begins with an investigation of current analytical techniques used in coastal management. This was pursued through the questionnaires; results are presented in Section 5.2. Coastal managers' expectations of using GIS to support analytical requirements of multiple use coastal management are discussed in Section 5.3. Specific analytical models developed and implemented in the Barkley Sound workshops are described in Section 5.5. Section 5.6 concludes with a discussion on the main findings regarding analytical requirements and the implications for the design and implementation of a Coastal SDSS. The discussion includes an evaluation of the models implemented and an assessment of the suitability of GIS to support the analytical requirements.

5.2 MULTIPLE-USE COASTAL MANAGEMENT TECHNIQUES

Despite the proliferation of coastal management initiatives, there are surprisingly few examples published on specific methods and techniques used to develop the strategies that are produced (see for example U.S. Department of Commerce, 1993; Clark, 1990). Whereas the general decision-making process may be described in reports and papers, methodological details are passed over with phrases such as, "what eventually emerged from the year-long process was a zoning plan" (respondent's quote) or "a plan was delivered by a consultant" (respondent's quote). Therefore, in Phase II of the questionnaire information was directly sought from decision-makers to supplement the information on current analytical techniques acquired from the literature review discussed in Section 2.4. Based on the general decision-making approach that emerged from Phase I, techniques to both generate and evaluate alternatives were sought. The question was phrased in such a way that the respondents were placed in a teaching position and asked to identify topics, methodologies, techniques or procedures which they would teach in each of the two subjects (generating alternatives and evaluating alternatives) as they relate to multiple-use coastal management.

Generating Alternatives

Methods used to generate alternatives could be categorised into three main headings:

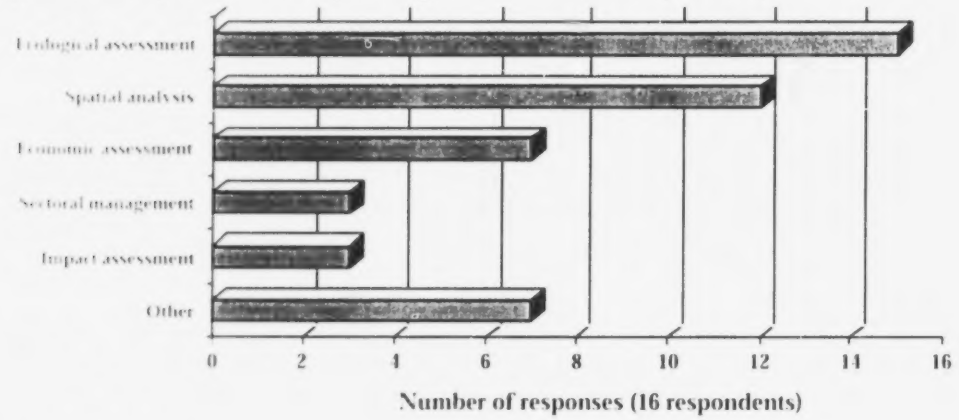
- Information Support;
- Analysis and Techniques; and
- Planning and Process.

Despite the analytical emphasis of the question, the majority of the responses related to Information Support, particularly the acquisition and management of a comprehensive database. These will be further discussed in Section Six. Planning and process included such elements as brain-storming, conflict resolution techniques, consensus building and role playing.

The intent was to ascertain specific techniques and methodologies which could be used in multiple-use coastal management. Responses which specifically related to techniques and methodologies were divided into five groups (Figure 7) although the responses were characterised by great variability and in many cases generality. The most common grouped techniques included Ecological and Environmental Assessment. These included environmental

impact assessment, determining carrying capacity, and principles of ecology. Almost as many responses were received on spatial analysis with particular emphasis on mapping techniques and GIS; however no details were given on specific methodologies. It is interesting to note that while 3% of respondents mentioned GIS in this question, when specifically asked if they would cover the subject of GIS in a course on multiple-use coastal management in a following question, 83% said they would use it.

Figure 7: Analysis and techniques to generate alternatives (Phase II)



There were few responses which specifically referred to methods of generating alternatives as opposed to information or assessments that would contribute to an understanding of alternatives. These included:

- generate future states based on different social / economic / environmental assumptions;
- develop a model that describes current conditions and then decide which variables to manipulate to develop alternative scenarios;
- describe scenarios which give priority to each key resource;
- plan from single purpose point of view, then combine and negotiate alternate scenarios; and
- lateral thinking;

In addition, several commented that the exploration of alternatives cannot be divested from their evaluation. Often it is an iterative process in which evaluating alternatives leads to the generation of new ones.

Evaluating Alternatives

Phase II questionnaire recipients were also asked to identify methodologies, techniques or procedures for evaluating alternatives they might teach in a course on multiple-use coastal planning. As with the responses for generating alternatives, responses for methods to evaluate alternatives were diverse and in many cases very general such as "compare scenarios", or use "evaluative criteria". However, a dominant group of techniques identified for evaluating

alternatives is impact assessment, namely economic, environmental and/or social. Traditional cost-benefit analysis was suggested in terms of natural resources, environmental quality and economic viability. Ranking and weighting methodologies were suggested for specific criteria such as economic, social impacts, regional strategies, jurisdiction, political will and research data as well as overall ranking for alternatives. Negotiation, consensus-building, round table procedures and simulations were identified as group processes used to evaluate altrnatives.

5.3 GIS FOR ANALYTICAL SUPPORT

In the preceding section, the generic characteristics of analytical techniques for coastal management were explored. This builds the foundation upon which to introduce GIS to the discussion. As with the previous section on decision-making, the problem is addressed first, followed by an investigation of GIS as a tool. Three areas are addressed with respect to GIS and coastal analysis: the use of GIS as an analytical tool, perceived strengths of GIS pertaining to analytical support, and similarly, their perceived weaknesses.

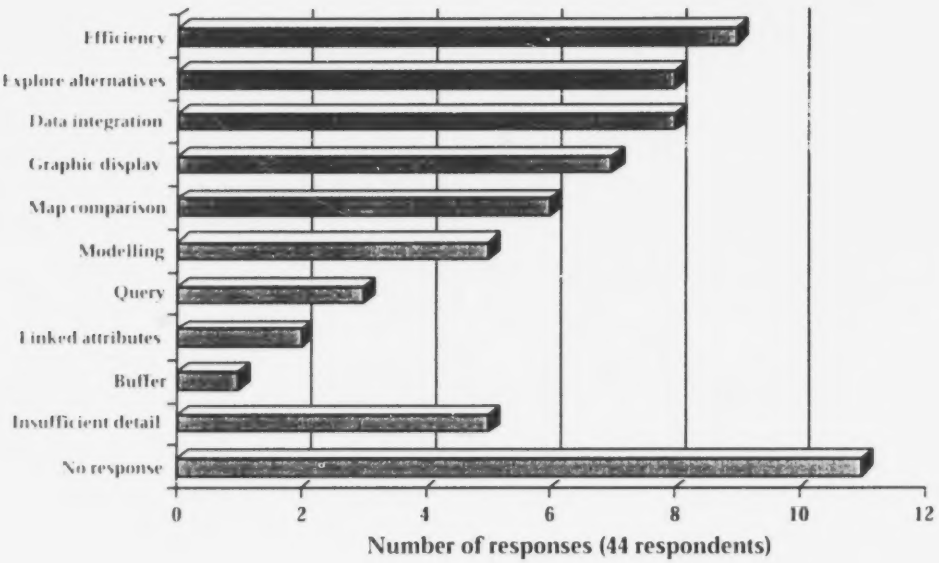
Analytical Implementation of GIS

Almost 40% of respondents in Phase I noted that GIS was used in the processes in which they were involved. GIS was used primarily for inventory and graphic display in 41% of these initiatives. In the remainder analytical implementations, the primary use of GIS was to evaluate spatial competition by overlaying various themes and identifying areas of overlap. The overlay was also used to identify target areas such as sensitive areas, priority areas, suitability areas and "no-go areas" based on specified criteria. GIS were used to explore and evaluate scenarios although no details were given on the analytical method used. Two respondents reported that other computer systems were used particularly for hydrodynamic modelling. Although GIS have been used extensively to support analysis for sensitivity analysis and emergency contingency planning, these fields were not represented by the respondents.

Strengths of GIS for Analytical Support

Questionnaire recipients were asked to describe the perceived strengths of GIS for analytical support to multiple-use coastal management. As with responses to analytical techniques for generating alternatives discussed above, many of the responses did not specifically relate to analytical capabilities. Instead, the responses focused on other functions such as integration of large data sets, graphic display and query which, combined, accounted for 64% of detailed responses (Figure 8).

Figure 8: Strengths of GIS for coastal analytical support (Phase I)



The most common analytical strength of GIS identified was their general efficiency and flexibility in manipulating and analysing data. Although this strength does not identify a specific analytical capability, efficiency and flexibility were identified as particularly conducive to exploring data, and testing new ideas and plans. Specifically, new scenarios could be generated by easily altering parameters. The exploration of alternatives was specifically mentioned by 29% of respondents who answered this question in detail. Similarly, VI CORE representatives highlighted GIS' efficiency and flexibility with respect to exploring 'what-if' scenarios, both with pre-defined parameters and interactively. Participants of the Barkley Sound workshops noted GIS' efficiency and flexibility as contributing to "progressive discussion".

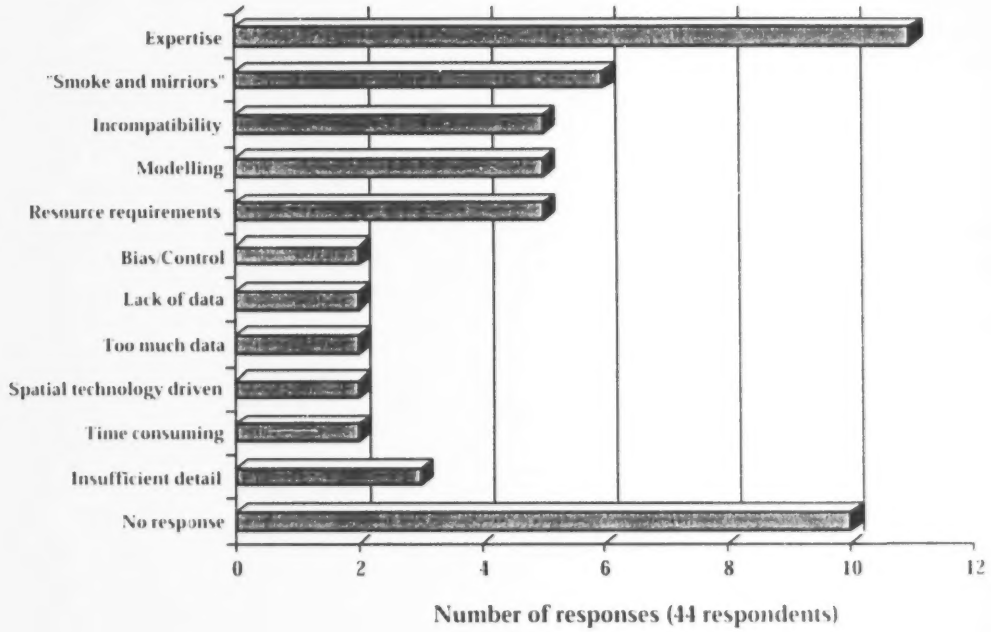
Specific analytical capabilities recognised by the questionnaire respondents included the overlay. Overlaying several themes allowed users to compare maps thereby revealing relationships, cross-correlations and spatial conflict among various data themes. The general expectation of GIS to develop models such as predictive models and to perform complex analysis was recognised, although no specific applications were suggested. It should be noted that 25% of respondents did not answer this question, often citing inadequate knowledge of GIS.

Weaknesses of GIS for Analytical Support

By far the most often-mentioned weaknesses of GIS with respect to manipulating and analysing coastal data by Phase I questionnaire respondents were the expertise required and difficulty in learning software (Figure 9). GIS analysis was also seen as having the potential to

mislead decision-makers either unintentionally through seductive 'smoke and mirrors', or intentionally through the bias of those controlling the analysis and data manipulation. Several respondents noted the inadequacy of GIS to easily support advanced modelling, particularly with respect to GIS coastal models. The derivation of GIS coastal models was noted to be complicated by the complexity and dynamic nature of coastal data. GIS were regarded as promoting spatial technology as a 'technical fix', while neglecting 'subjective' or 'fuzzy logic' analyses of multivariate problems and data that cannot be easily represented spatially, such as spiritual and cultural values.

Figure 9: Weaknesses of GIS for coastal analytical support (Phase I)



In the previous section, efficiency in manipulating information was seen as a strength of GIS by all three target groups. In the VI CORE process it also proved to be a weakness. Several VI CORE interviewees commented that participants were "deluged" and "overwhelmed" with the volume of maps and areal calculations produced by GIS.

5.4 PILOT COASTAL SDSS

A pilot Coastal SDSS was developed based on information gathered on decision-making (Section 4), analysis (Section 5) and data (Section 6) compiled from four sources of information, namely:

1. literature survey;
2. questionnaires;

3. VI CORE interviews; and
4. preliminary Barkley Sound Float Cabin Sub-committee meetings.

The functions developed for the pilot Coastal SDSS were accessed through a customised menu interface also programmed in ArcInfo's™ Arc Macro Language (AML). The menu items are introduced here. Each is explained in more detail in subsequent sections.

1. **Inventory**[1] Display and query the database and report on data quality.
2. **Position**[1] Digitise participants' positions.
3. **Criteria**[1] Select and manipulate criteria for criteria analysis.
4. **Multi-use**[1] Evaluate results of criteria analysis.
5. **Consensus**[2] Evaluate group consensus on position and criteria analysis.
6. **GIS**[2] Access to full suite of GIS functionality.

[1]Incorporated in pilot Coastal SDSS for the workshops.
[2]Designed but NOT incorporated in pilot Coastal SDSS for the workshops.

This section focuses on the analytical functions of the pilot Coastal SDSS. The design guidelines, relevant to analysis, derived from the above sources are summarised in Table 7. The analytical functionality of the pilot Coastal SDSS was programmed in ArcInfo's™ AML.

5.5 ANALYSIS IMPLEMENTED IN PILOT COASTAL SDSS

To meet the above guidelines two analytical applications were developed:

1. *Position analysis* - focuses on participants' conceptions of solutions to the issue at hand by delineating their preferred outcome.
2. *Criteria analysis* - focuses on revealing the spatial distribution of stakeholders' underlying interests and revealing areas of multiple use conflict.

A third analytical application, consensus evaluation, was considered to determine the area and degree of agreement among stakeholder's interest maps. An interest map is a spatial representation of a stakeholder's interests combining the factors each considers relevant and their weighting of those factors. However, due to time constraints, consensus evaluation was not incorporated in the pilot Coastal SDSS. The following sections describe position analysis and criteria analysis as they were developed and implemented in the Barkley Sound workshops. Consensus evaluation is discussed in Section 7. Throughout the following discussion there are two points to be kept in mind:

1. The Barkley Sound Float Cabin Sub-committee were charged with developing a strategy to locate and regulate float cabins in Barkley Sound. It was generally understood within the Sub-committee that coalescing the dispersed float cabins into communities was preferred to evicting trespassing cabins or legitimising the *status quo*. Towards this aim, various issues need to be addressed which are integral to locating communities. These issues include the number of cabins to constitute a community, administrative arrangements, environmental health regulations and other users. All these issues are being investigated in concert, but only the last issue was addressed in the workshops. The decision objective of the workshops was to explore alternatives for the location of float cabin communities in Barkley Sound while taking account of other users, resources and stakeholder interests.

2. The analytical results of the workshops were not the emphasis of the workshops. The research objective of the workshops, which was paramount to the decision objective, was to evaluate the role and effectiveness of GIS to support multiple-use coastal management in an interactive group setting using Barkley Sound float cabins as a case study. Therefore, analytical results from the workshops are discussed only as they are relevant to the research objective.

Table 7: Analytical design guidelines for the pilot Coastal SDSS

GUIDELINES	RATIONALE
• contribute to defining zonation schemes	The main output from a coastal management strategy described in the literature and exemplified by the VI CORE process and the Barkley Sound Strategy is a zonation scheme.
• incorporate subjective elements of stakeholders' values	Respondents to Phase I were critical of the potential of GIS to encourage a technology- driven process to the neglect of human input.
• degree of objectivity and rigour to substantiate decisions	Members of the Barkley Sound Float Cabin Sub-committee felt that incorporation of subjective elements should be balanced with objective rigour.
• transparent and understandable to the decision-makers	The VI CORE process showed that the use of GIS could be ineffectualised by, among other things, the 'black box' effect which could be overcome by emphasising participation and simplicity
• emphasise GIS strengths and one of the main analytical expectations of the decision-makers, namely, spatial overlay	Using functions which are familiar with decision-makers could also combat the 'black box' effect.
• reveal potential areas of conflict of uses	A common application of the overlay used by coastal managers as seen from the Phase I respondents is the ability to identify areas of spatial overlap is indicators of potential conflict.
• reveal interests and areas of agreement among stakeholders	An implicit goal of group decision-making is to reach agreement among the members.
• widely applicable to numerous coastal management initiatives	The variability of initiatives and process described by Phase I respondents shows that Coastal SDSS must be widely applicable to be useful.

Position Analysis

Depending on their familiarity with the issues and region, decision-makers may come to the table with an *a priori* conception of a preferred solution or they may develop a preferred solution during the process. The general intent of the group decision-making process is to converge the stakeholders' positions to a mutually agreed-upon outcome. By aggregating all stakeholders' positions through an overlay one can assess the degree of spatial agreement among the participants at appropriate stages throughout the process. At the onset of the process, this can gauge the level of pre-meeting consensus and initiate discussions by focusing on areas of agreement. Repeating the exercise throughout the process can gauge the degree of convergence as the process progresses.

Two weeks prior to the workshop participants delineated on individual maps their preferred distribution areas of float cabin communities in Barkley Sound. Twelve participants completed

the maps; four participants reported having no specific preferences to the location of float cabins at that time and did not complete a map. The maps submitted ranged from a written list of areas, to broad circles around regions, to precisely delineated boundaries. In the case of broad circles, these were amended to conform to nearest coastal boundaries. The twelve maps were digitised and aggregated by overlaying all participants' maps. A user-specified classification scheme of frequency presents level of agreement among the participants.

Four observations can be made from the results of the position analysis conducted prior to the workshops (Figure 10). Firstly, this analysis shows the level of pre-meeting consensus. The aggregate maps immediately highlight those areas of agreement. There were three areas unanimously designated across both workshops. These three areas could represent starting points for discussion. Secondly, superimposing existing float cabins with the position analysis results enables decision-makers to see how many cabins are outside preferred locations. These cabins could be targeted for re-location. Thirdly, the results give an indication of the propensity of decision-makers to explore new alternatives. As was stated above, four participants reported having no preference to float cabin locations, indicating that they were open to exploration. The remainder of the participants showed a strong preference to accommodate float cabin communities where float cabins are currently located, perhaps indicating that they are less likely to explore new alternatives. Finally, the results of position analysis can be compared between workshops. While participants in Workshop #2 generally focused their preferences in areas with a higher density of float cabins, participants in Workshop #1 were more inclined to demarcate any areas with float cabins regardless of the density. This could indicate that participants in Workshop #2 were more willing to accommodate the re-location of float cabins than those in Workshop #1. In summary, the main contributions of the position analysis was to indicate the level of agreement among participants, to suggest avenues of pursuit, and to gauge participants' problem-solving approach.

Criteria Analysis

As an alternative to the position analysis, a criteria-based approach was developed with a primary emphasis on distilling the problem to a set of decision criteria, thereby revealing the underlying interests of the participants. Three factors were considered to contribute to participants' underlying interest:

- the criteria they consider relevant to determining float cabin locations;
- the importance placed on each criterion; and
- whether that criterion is considered compatible or incompatible with float cabins.

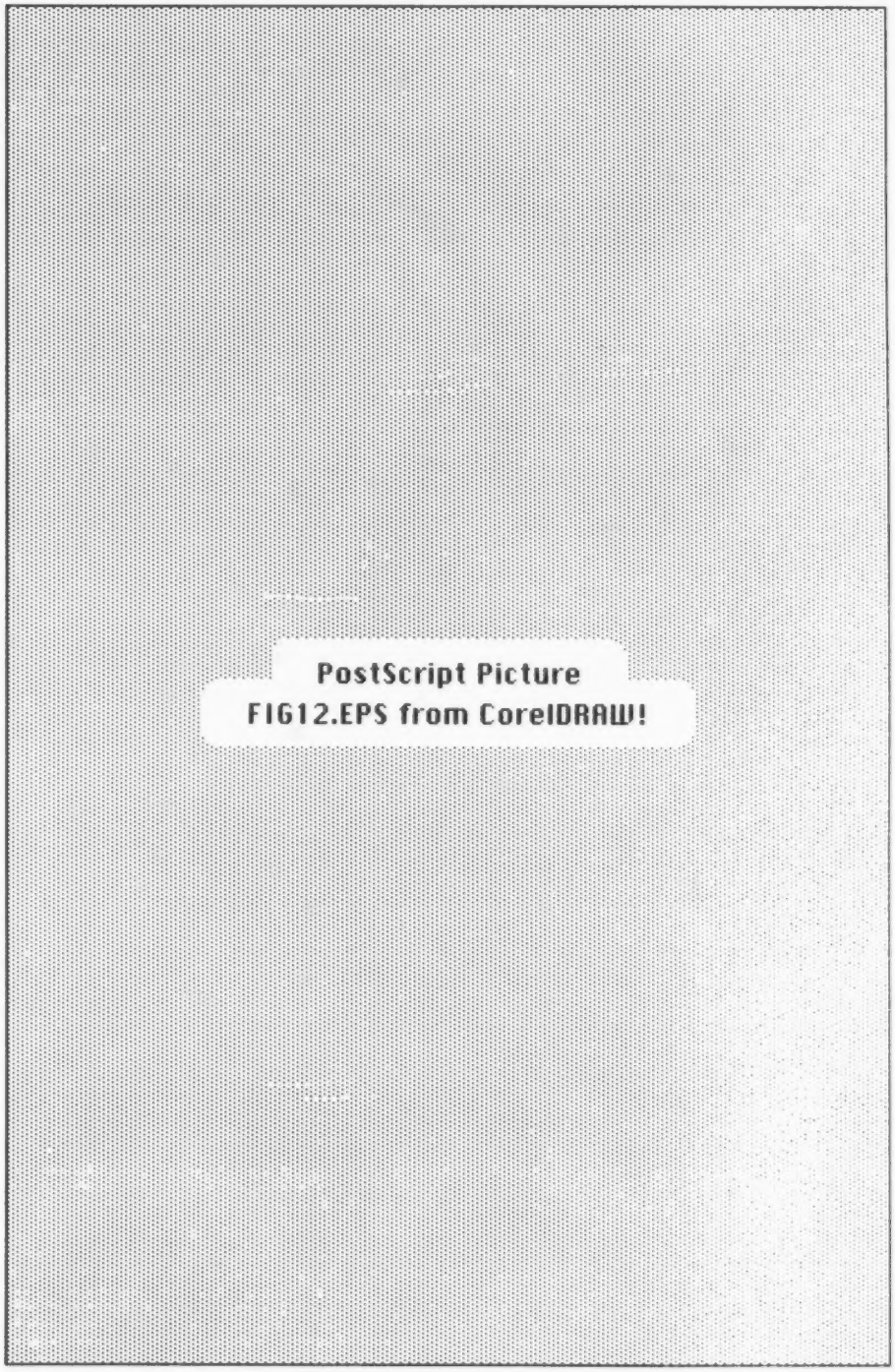
The spatial representation of those interests can be used to depict the areas of preference for float cabin development and areas of conflict according to each participant. As with position analysis, a group map can be aggregated and a level of agreement or disagreement derived.

Identification of criteria

The first step in the analysis is to identify the criteria considered relevant to the problem. In this exercise identification of criteria was constrained by pre-existing data layers such that each data layer represented a potential criterium. Identifying decision criteria and objectives is one of the most important steps in decision-making following the establishment of an overall goal. Decision criteria structure the decision problem and establish indicators upon which

alternatives are evaluated relevant to the overall goal (Keeney, 1988). The number of criteria identified at this stage is important since decision-makers will be asked to compare and rate the criteria. Too many criteria might make it difficult to compare, while too few criteria may not account for all stakeholders' interests. The general number of elements to compare and rate considered to be appropriate is eight (Buchanan, 1994; Voogd, 1983; Edwards, 1977).

Figure 10: Aggregate position maps prior to the Barkley Sound workshops



Due to time constraints during the workshops, criteria were selected prior to the workshops. Four weeks prior to the workshops a questionnaire asked participants to identify and rank criteria they deemed relevant in determining where float cabins should and should not be located. The criteria for all participants were assimilated based on frequency of mention and rank. It was not possible for all workshop participants to discuss this exercise prior to finalising the criteria list. However, the criteria were discussed at a meeting of the Barkley Sound Float Cabin Sub-committee for refinement. From these discussions and based on available data, an initial list of eight criteria was established. These were programmed in the Coastal SDSS using a button menu. The same criteria were used for both workshops:

NATURAL ENVIRONMENT	HUMAN ENVIRONMENT
Key marine habitats	Archeological sites
Wetlands	Commercial - recreation
Clam beds	Log storage
Grey whales	Mature forest productivity
Herring spawning	Private land
Upland sensitive	Recreational boating
'Visually sensitive'	Shellfish leases

Criteria weighting

It was then necessary to capture the underlying interest of each participant with respect to the importance of each criterion and their assessment of compatibility. Techniques for capturing stakeholder values have been discussed elsewhere and a brief discussion is presented in Appendix B. The key to capturing stakeholder preferences for multiple weighted overlay can be summarised in three points. The method should:

1. be intuitive to the decision-maker (Bryson *et al.*, 1994);
2. accommodate the imprecision of stakeholder input (Bryson *et al.*, 1994); and
3. derive interval or ratio weightings which are true to the stakeholders' expectations and infer no more regarding the degree of importance than the information that was acquired (Buchanan, 1994).

The technique chosen to acquire stakeholder input is budget-based. Stakeholders were given a 100% budget with which to allocate their interest among several decision criteria. They could not exceed their 100% budget and they had to allocate their entire budget, although some criteria may receive a budget value of zero if deemed irrelevant.

Again, in order to make maximum use of the time available during the workshops, participants were asked to rate the criteria prior to the workshop. The weighted scheme was programmed in the pilot Coastal SDSS using a 'slide-bar interface'[3] although participants used a parallel manual method using graph paper. In addition to assigning an importance value to each criterion, users also assessed the compatibility of a criterion; in this case compatibility is assessed relevant to float cabins. If a criterion is deemed to be incompatible, that is, where this

criterion is present these are areas to avoid, it receives a negative weight. If a criterion is deemed compatible, that is, where this criterion is present the area is considered potentially suitable for float cabins, it receives a positive weight. Users using the slide bar interface are alerted when their total of the absolute weights does not equal 100. Stakeholders only rate those criteria selected for the current iteration. For a different set of criteria, an individual criterion might receive a different weighting value. Therefore, it does not assume that there is one inherent weighting value for a criterion but the value is dependent on the other criteria in the set.

From the weights it is possible to assess:

- how individual interests are represented by the weights, for example, which participants have a strong preference for one or two interests *vs.* a more egalitarian preference;
- agreement on compatibility classification, for example participants were unanimous in their compatibility classification of 'recreational boating' (compatible) in Workshop # 1, and 'key marine habitats' (incompatible) in Workshop #2;
- agreement on tendency of compatibility classification by comparing the total negative weights and total positive weights; and
- consistency between individuals representing the same stakeholder group, for example in all cases there is inconsistency between representatives on the compatibility classification of at least one, and at most three, criteria.

Participants commented that they found the weighting exercise to be challenging. In part, this was due to insufficient discussion allowed by the time constraints of the workshops. Although the weighting method was understood, it was unclear to many how their weightings were to be manipulated. Difficulties also arose in interpreting the meaning of each criterion, thinking about tactical strategies, and assigning a compatibility index. Participants variously interpreted terms of the criteria. For example, 'scenic value' was interpreted to mean 1) attraction of scenic surroundings for float cabin owners; 2) impact of float cabins on wilderness scenery; and 3) visual impact of float cabins in terms of structure, colour, construction etc. Secondly, several participants deliberated over the tactics that could be employed in assigning weights. For example, a weighting scheme that is most beneficial to a particular interest may not be that which contributes to creating solutions for the group. Hence, there is also the possibility to exert position-based bargaining power in this approach. Finally, several participants found it difficult to assign a compatibility index to some criteria particularly because some did not consider it to be a binary assessment, compatible *vs.* incompatible. Often these assessments were influenced by attributes of an activity or resources, or by a distance factor. Some of these challenges were addressed during the workshops when the procedure was repeated as a group exercise, described below.

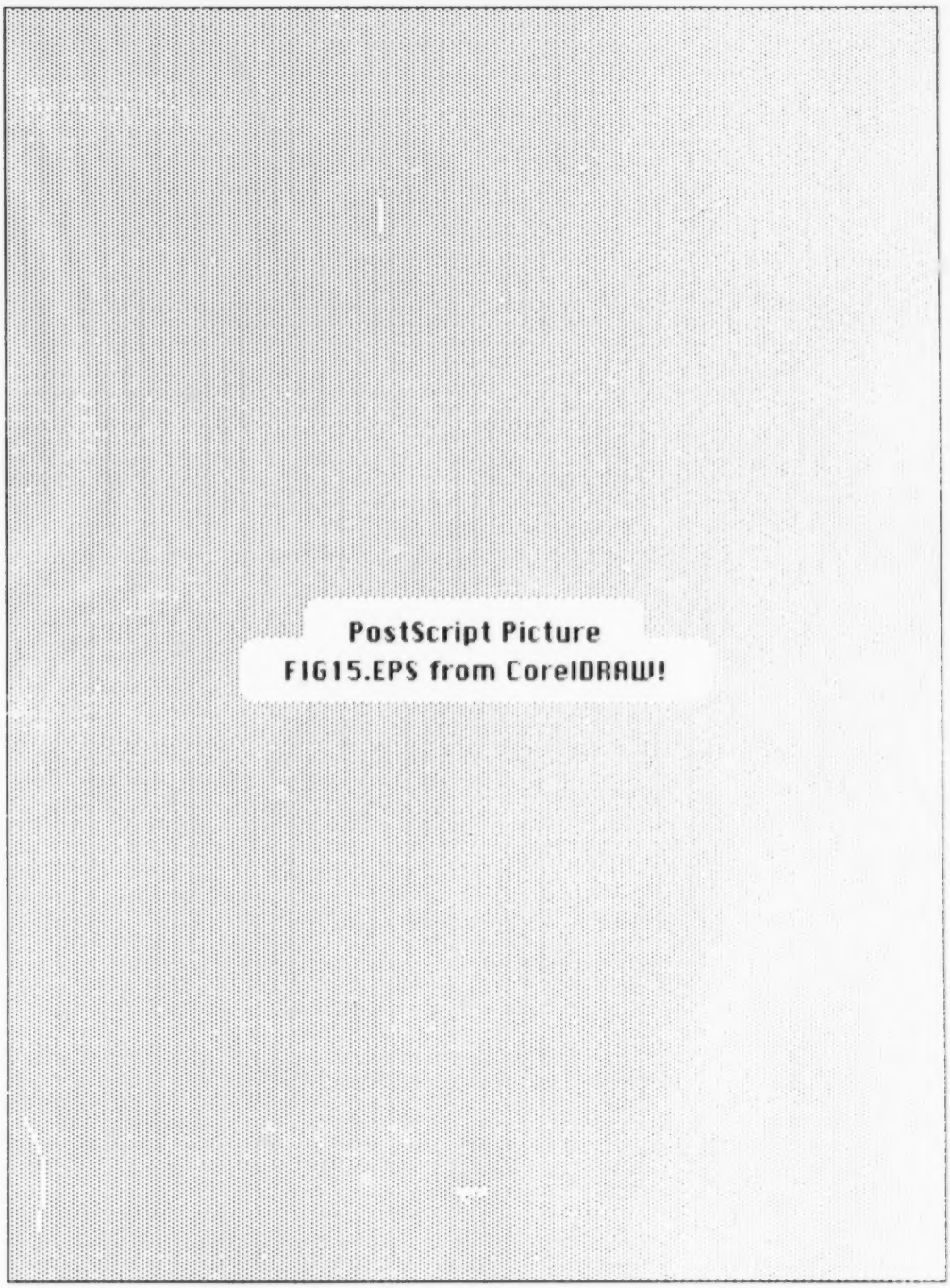
Stakeholder interest maps

The weights identified by each participant prior to the workshop were stored as attributes of each map layer. All criteria data layers were then combined in successive pairwise overlays. As one polygon overlaps an existing polygon from another data layer, a new polygon is formed. The weightings for all criteria in each polygon created from the multiple overlay were summed to derive an overall weighting. The overall weighting should represent the degree of polygon compatibility (or incompatibility). The example in Figure 11 representing an individual

stakeholder's weighting of five criteria and the following discussion illustrate the procedure followed to create stakeholder interest maps.

Various approaches could be pursued to compile the weightings and create an overall rating for each polygon. Most simply, all weights could be summed and stored as a single attribute, 'weight'. All those polygons with a total greater than zero are assigned class 'Compatible', all those less than zero are assigned class 'Incompatible' and all those equal to zero are designated 'Neutral'. However, this approach does not give an indication of the nature of any potential conflict among criteria such as occurs in polygons 2, 7, and 8 which contain both compatible and incompatible weightings, but merely assumes that a larger weight nullifies all other competitive values.

Figure 11: Example of criteria weight manipulation



A second approach is to sum total positive weights and negative weights in separate attributes, '+' and '-'. Those polygons having only compatible criteria are classified 'Compatible' and those having only incompatible criteria are classified 'Incompatible'. Those polygons containing both compatible and incompatible criteria are classified 'Mixed'. This eliminates the nullifying effect discussed above and isolates potential conflict areas. The Multi-Use function generates a graphic display (Figure 12) of the results. Alternatively, a report summarising the results could be generated.

At first glance, the issue of float cabin communities is primarily a water-use issue. However, the criteria selected by the participants were mostly land-based resulting in designations of compatibility and incompatibility shown mostly on land. In coastal issues such as this the immediate upland considerations are equally important as marine coastal areas and form the only basis of judgement in the absence of marine criteria. In the case where a 'Mixed' coast is backed by an 'Incompatible' coast the landward extent of impact from the float cabin communities should be taken into account. This factor could also be included in the model by defining a maximum distance of landward impact.

This 'Overview' procedure focuses on the compatibility/incompatibility designation and ignores the degree of importance represented by the weightings. As a result, while this procedure is useful for a broad examination of potential solution areas, it may not give adequate detail to assist decision-makers. Users, therefore, have the option to refine any one or all of the classifications derived from the 'Overview' analysis based on weightings. For compatibility and incompatibility classes, users can specify the range of three sub-classes, High, Moderate and Low. Again, the results can be displayed on a map (Figure 13). By running this procedure several times to finalise sub-class intervals depending on the overall range of weights, one can assess the sensitivity of the results.

With respect to refining 'Mixed' classification, there are several potential scenarios to consider. Referring back to the example in Figure 11, polygons 2 and 8 are classified as 'Mixed' with a total weight of zero. However, the magnitude of the weightings indicates that polygon 8 warrants greater scrutiny because of the high weightings suggesting a higher potential for conflict. A second scenario to consider is a case when the total compatible and incompatible weightings are imbalanced such as polygon 7. In this case the 'Mixed' polygon can be considered to have a strong incompatible tendency. In order to account for these scenarios four subclasses were created from a 'Mixed' class, 'Mixed-Low', 'Mixed-High', 'Mixed-Compatible' and 'Mixed-Incompatible'. The boundaries of these classes are user-defined by specifying two parameters: the percentage difference between total negative weights and total positive weights, and a magnitude threshold.

The parameters in the algorithm are manipulated according to the following rules:

For all polygons designated '**Mixed**',

1. If $|+/-| = m$ and $+ > n$,
the polygon is designated '**Mixed-Low**'

2. If $|+/-| = 1/p$,
the polygon is designated '**Mixed-Compatible**'

3. If $|+/-| > p$,
the polygon is designated '**Mixed-Incompatible**'

4. Else, polygon is designated '**Mixed-High**'

Where m = minimum weight,
p = minimum percent difference,
$\Sigma+$ = sum of all compatible weights in a polygon
$\Sigma-$ = sum of all incompatible weights in a polygon

Figure 12: Graphic display of results from MULTI-USE - Overview

Figure 13: Graphic display of results from refining compatibility and incompatibility classes

'Mixed-Low' indicates that both compatible and incompatible criteria occur in a polygon, but with low weights for both. 'Mixed-Compatible' indicates that both compatible and incompatible criteria occur, but the weights are skewed towards compatible, exceeding the minimum percent difference specified. 'Mixed-Incompatible' indicates that both compatible and incompatible criteria occur, but the weights are skewed towards incompatible, exceeding the minimum percent difference specified. 'Mixed-High' indicates that none of the above conditions are satisfied. These are potentially conflicting areas containing both compatible and incompatible criteria with weights exceeding the minimum weight specified and skewed towards neither compatible nor incompatible. Table 8 illustrates this procedure. Again, results could be shown graphically or in tabular form and repeated analysis will examine the sensitivity of the solutions to the thresholds specified.

Table 8: Manipulating weights in 'Mixed' polygons

?+	?-	?+/?-	Class	Explanation
5	-5	-1	Mixed - Low	Condition 1
40	-40	-1	Mixed - High	Condition 4
80	-20	-4	Mixed Compatible	Condition 2
10	-50	-.2	Mixed - Incompatible	Condition 3

where $m = 10$, and $p = 0.25$.

Comparison of stakeholders' position-based and criteria-based results

Ideally stakeholders' interest maps (spatial representation of factors considers relevant and weighting thereof) should be reflected in their position maps (delineated preferred areas). It is expected that the position areas delineated would correspond to areas of compatibility and would not contain areas of incompatibility. A comparison of an individual stakeholder's position and interest maps is shown in Figure 14. It shows that small portions of preferred areas were determined to be incompatible or mixed according to the criteria used and the decision-maker's weightings. In addition, there are several areas within this region which were determined to be compatible and not contained in the areas designated by the stakeholder. These indicate areas to explore which potentially could accommodate float cabin communities beyond the stakeholder's pre-conceptions. However, caution must be used not to place undue emphasis on this conclusion since it does not take into account the areas which, for physical reasons such as depth and exposure, could not accommodate float cabin communities.

Comparing the percentage of areas delineated in all stakeholders' positions maps with the multi-use categories shows that on average 25% of the coastline designated as a preferred area were designated as 'Compatible' (Table 9). However, a higher average of 42% of the coastline designated as a preferred area was designated as 'Incompatible'. This indicates that according to the criteria selected and weighting scheme, on the whole the stakeholders' position maps were not reflected by the interest maps. Three exceptions are Stakeholders 1-3, 1-7, and 2-7 whose interest maps more closely reflected their position maps.

Figure 14: Example of a comparison of a stakeholder's preferred area designation and results from multi-criteria analysis

Table 9: Linear percentage comparison of position and interests maps

Stakeholder	Total length of coast delineated (km.)	% Compatible	% Incompatible	% Mixed
1-1	35	26%	89%	6%
1-2	54	19%	61%	15%
1-3	35	91%	3%	6%
1-4	74	12%	64%	9%
1-5	131	7%	60%	11%
1-6	39	15%	69%	10%
1-7	83	49%	10%	10%
Group 1 avg.	***64***	***31%***	***51%***	***10%***
2-2	51	10%	59%	8%
2-3	57	12%	4%	0%
2-4	64	9%	75%	6%
2-5	98	8%	0%	0%
2-7	66	45%	15%	7%
Group 2 avg.	***67***	***17%***	***31%***	***4%***
Total avg.		***25%***	***42%***	***7%***

Group interest maps

All stakeholder's maps can be combined to produce a group interest map. The general procedure is to derive a group weighting as some combination of stakeholders' weightings for each criterion. The group weighting is then manipulated in the same overlay and summation method as the stakeholder interest maps. There are two elements to consider in deriving a group weighting from stakeholder's individual weightings:

- magnitude of the weighting value
- compatibility/incompatibility index

The most common definition of a group value is the mean of stakeholders' values. However, this measure is very susceptible to outliers and tends to distort individual preferences (Spillman *et al.*, 1980). An alternative approach is to calculate a group value which minimises the distance between stakeholder values (Bryson *et al.*, 1994) according to the equation,

$$\text{Minimize} \sum_{i=1}^{n} |W_i - W_g|$$

where n = number of stakeholders
w_i = weight assigned by stakeholder i
w_g = group weighting to be solved.

The minimised distance value was calculated as the group weighting for each criterion. The objective function was programmed in MicroSoft Excel™ and the result transposed as an attribute. Increasing compatibility between statistical packages and GIS would have enabled direct calculation of the group value.

The second element of the group weighting to consider is the compatibility/incompatibility index. In cases where all stakeholders agree on the compatibility/incompatibility index the group weighting is the actual minimised distance value. However, within the Barkley Sound Workshops unanimous agreement on the compatibility and incompatibility index was only achieved for one criterion in Workshop #1 and two criteria in Workshop #2.

In such cases a similar approach was followed as was described above in resolving the problem of a polygon containing both incompatible and compatible criteria. The decision rule sums the total incompatible weights and compatible weights separately. A minimum percentage difference is calculated representing how much one can outweigh the other in order for the dominant index to be assigned. If the difference is less than this threshold, or minimum boundary, then this criterion is flagged as conflicting among the decision-makers, and where that criterion occurs is identified graphically.

The application of this method is shown in Table 10. An example was illustrated using a 25% differential to resolve differences in compatibility index. The group values in italics show those criteria which do not meet this differential threshold. The sensitivity of the results can be assessed by varying the percent differential threshold.

Table 10: Stakeholder weightings and group values for the workshops

(a) Workshop #1

	KMH	SV	WS	AS	LS	RB	SA	PP
?+	17	44	3	31	5	44	29	28
?-	-209	-10	-75	-181	-65	0	-90	-61
%?	0.08	.23	0.04	.17	0.08		29	46
Group value	-20	7	-8	-18	-5	5	*44*	*20*

(b) Workshop #2

	KMH	SV	WS	AS	LS	RB	SA	PP
?+	0	22	23	10	0	31	29	5

?-	-179	-20	-31	-168	-61	-7	-132	-77
%?		.91	.72	.06		.23	.20	.06
Group value	-24	4	-7	-19	-7	3	-13	-7

KMH = Key Marine Habitats; SV=Scenic Value; WS=Wildlife Sensitive; AS = Archaeological Sites; LS= Log Storage; RB = Recreational Boating; SA = Shellfish Aquaculture; PP = Private Property

During the workshops participants chose to repeat the analysis using a new set of criteria (Table 11) and a new group interest map was generated. Upon the direction of the group, the compatibility and incompatibility indices were revised to identify those criteria that were unequivocally incompatible and those which were potentially incompatible. In other words, no criteria were identified as unequivocally compatible. Secondly, due to time constraint, the criteria were not weighted differentially and all were given equal weighting in the analysis. In both workshops, native reserves, private land, aquaculture operations and marine habitats and natural resources were included in the analysis. In addition, both groups included a designation from the Barkley Sound Strategy. In the second workshop, commercial lodges and log storage also were included. The importance of considering not only the presence of a criterion but also the distance between potentially incompatible activities or resources was recognised by the participants in defining criteria. The distance function was incorporated in two ways. Firstly, buffers were created around relevant features to create a new map layer. The second approach, used more frequently in the second workshop, used the ArcView interactive distance query and radius tool to highlight features falling within a specified distance. The interactive display and query functions are discussed more fully in Section 6. In addition, due to the dynamic nature of the marine environment, a variable width buffer determined by flushing rates would be more suitable in some cases than a uniform width buffer around a feature.

Table 11: Revised criteria

(a) Workshop #1

Criteria	Compatible	
	No	Maybe
Native reserves	v	
Shellfish aquaculture < 200m	v	
Fish farm <200m	v	
Private land		v
Eelgrass	v	
Estuary <100m	v	
Aquaculture Priority Area		v

(b) Workshop #2

Criteria	Compatible	
	No	Maybe
Native reserves <1km	v	
Shellfish aquaculture	v	
Fish farm		v
Private land		v
Key marine habitats	v	
Clam beds	v	
Oyster beds	v	

Fish streams <300m	v	
Herring spawning	v	
Log storage	v	
Lodges	v	
Marine Recreation Area		v

The results of these workshop analyses for a portion of Barkley Sound are presented in Figure 15. The multi-criteria results were overlaid with existing float cabins to identify cabins which are not in apparent conflict, cabins which are in conflict, and cabins which are potential candidates for relocation. The most significant differences between the results of the two workshops in this region of Barkley Sound is the designation of Useless Inlet as 'Potentially Compatible' in Workshop #1 and the designation of north-western portions of Uchucklesit Inlet and parts of Rainy Bay as 'Incompatible' in Workshop #2. In addition, during Workshop #1 the results of the analysis were used to identify areas which could accommodate additional float cabins.

5.6 DISCUSSION AND SUMMARY

This section has addressed the analytical requirements of Coastal SDSS for multiple use coastal management. Design guidelines were derived from a literature survey, the questionnaires, VI CORE interviews, and observations of the Barkley Sound Float Cabin Sub-committee. From these sources, a pilot Coastal SDSS was developed using ArcInfo's™ Arc Macro Language programming. The Coastal SDSS was then implemented in two workshops. The decision objective of the workshops was to explore alternatives for the location of float cabin communities in Barkley Sound while taking account of other users, resources and stakeholder interests. The issue was investigated in the workshops with members from eight relevant stakeholder groups. Although the Barkley Sound case study set a context for the implementation of a Coastal SDSS, the research objective of the workshops was its driving force. The research objective of the workshops was to evaluate the role and effectiveness of GIS to support multiple-use coastal management in an interactive group setting.

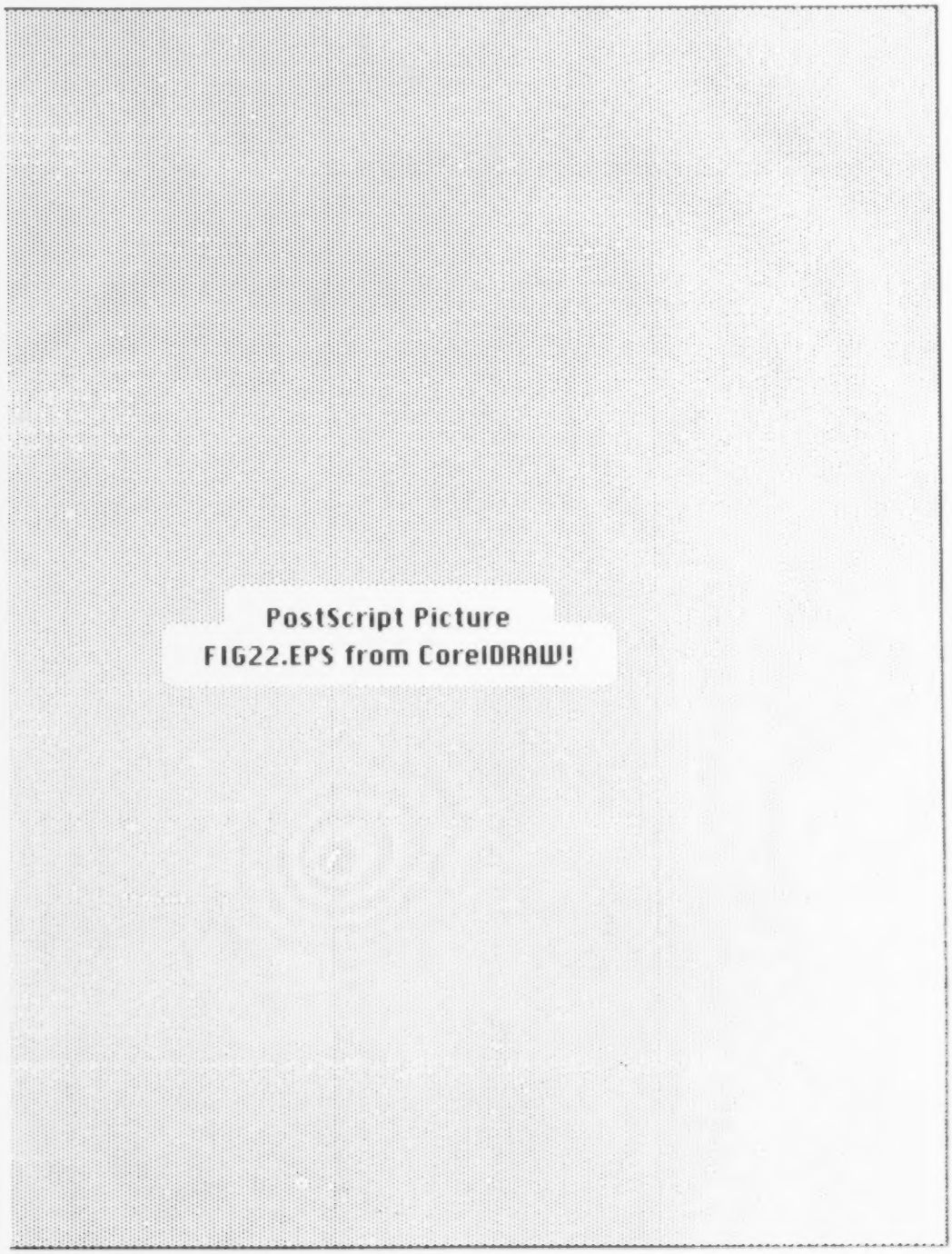
Analytical Design Guidelines

Given the paucity of information in the literature about specific analytical techniques used in coastal management, information was sought at first hand from coastal managers through a questionnaire. Responses to the questionnaires gave less insight into specific analytical techniques used in multiple-use coastal management than was anticipated. Several suggestions can be presented in this regard. Standard and widely used techniques simply may not exist. Each coastal management initiative is unique, requiring techniques to specifically suit the application. The result is that in terms of analytical models most coastal managers have to start afresh developing and applying 'new' models and methods. Alternatively, the apparent *ad hoc* and involved approach makes it difficult to pinpoint specific techniques, but rather such an approach is characterised as a gradual evolutionary process. In addition, the decision-makers surveyed may be sufficiently removed from the analytical procedures, instead relying on technical advisory groups for such input. A third suggestion is that the emphasis of coastal

management lies in decision-making processes and inventory, rather than on analytical techniques. With the exception of 'innovative problem solving', analytical techniques were not included in success factors for coastal management. Decision-making processes, on the other hand, particularly group process skills such as consensus-building, negotiation and conflict resolution, were raised as techniques for both the generation and evaluation of alternatives. This emphasis is evidenced in the VI CORE process in which participants were given extensive training in group process skills and limited training on problem-solving and analytical skills.

The predominance of environmental interests described in Section 4.2 is reflected in the use of ecological assessment techniques for both the generation and evaluation of alternatives. Spatial analysis also was recognised as an important group of techniques. However, as with ecological and economic assessment, the direct link describing how these might contribute to generating alternatives was not made. Few techniques were suggested which directly generate alternatives and these focused on multi-variable manipulations in which numerous variables relevant to the problem are manipulated in different combinations to create various outcomes.

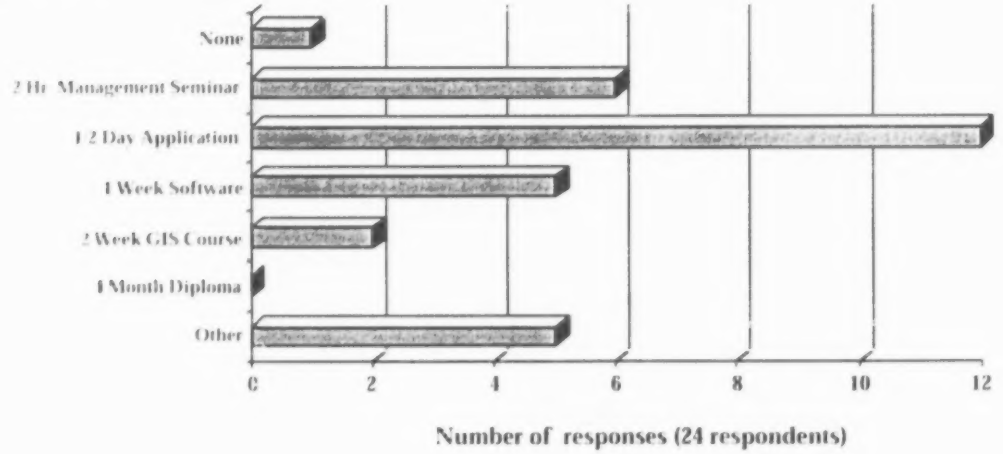
Figure 15: Revised multi-criteria analysis conducted during the workshops



The emphasis of GIS functions for data integration, inventory and display repeatedly emerged in questions relating to analytical techniques. From these results we can deduce that the inventory and display capabilities of GIS outweigh the analytical capabilities according to the decision-makers polled in the surveys. Alternatively, the results imply that respondents may have been primarily exposed to the inventory and display functions of GIS and have generally little familiarity with the analytical functions. GIS is "usually developed for high end scientific uses, not day-to-day managerial uses" (questionnaire respondent). Examining the GIS experience of Phase I respondents lends support to the second suggestion, as almost two thirds of Phase I respondents had none or limited exposure to GIS in the form of demonstrations, seminars or review of output. It is likely that such limited exposure was graphically oriented towards GIS' eye-catching displays rather than hands-on analytical exploration.

The expertise required to operate GIS analysis noted by respondents was seen as an impediment to using GIS as an analytical tool by coastal managers. In order for GIS to be placed in the hands of the decision-makers for analysis two efforts must be pursued. In the first instance, decision-makers must be better informed and trained on the types of questions and problems GIS can answer both generally and with respect to the specific analysis implemented. This was also supported by comments from VI CORE participants who noted that while they had abundant technology and expertise available and despite a demonstration on GIS, they were not adequately prepared to ask effective 'GIS questions' nor request specific analysis. When asked what level of training they felt was required, more respondents chose a half-day briefing on how to use the system for a specific application (Figure 16). The emphasis of training lay in going beyond demonstrations, but not extending to in-depth software training, or peripheral theoretical and technical information. Respondents clearly leaned towards training, on a 'need to know' basis, on what GIS can and cannot do, and on how to frame questions in a GIS context.

Figure 16: Preferred GIS training



A second approach to address the level of GIS expertise is to develop systems that are more user-friendly and approachable to decision-makers. One respondent noted, "GIS must (1) wait

for users to catch up to the technology or it will remain a glitzy novelty that is truly *used* by a small fraction of system owners, or (2) promote its utility and ease of use". Another respondent confirmed that it is necessary to "train the machines and not the users, so technical knowledge is less of a factor". This can be accomplished through customised user-interfaces and incorporation of analytical models familiar to decision-makers.

Workshop Conclusions

The limited practical contribution of the questionnaires with regard to coastal management techniques, placed more emphasis on the analytical models implemented in the pilot Coastal SDSS: position analysis and criteria analysis.

The position analysis presents several advantages and disadvantages to the decision-making process. In sub-regional and community initiatives, decision-makers are likely to be closely involved with the issues and can readily delineate their preferences. The procedure of aggregating participants' positions is easily manipulated in an overlay, probably the most standard and widely understood of GIS procedures. It can give a quick and direct measurement of group consensus, either at the onset of a process or to gauge progress. It can reveal participants' problem-solving approach. Position analysis can also provide direction to the process by focusing on areas of agreement. The procedure can be refined by incorporating preference ratings for various sites.

There are, however, certain limitations and disadvantages of using this analysis within a decision process. By initiating a decision-making process with position statements there is the possibility of limiting the scope of alternatives to pre-conceived ideas. There also may be less opportunity for exploring alternatives beyond these positions. In both Barkley Sound workshops, discussions focused on specific sites rather than on exploring potential new sites. However, it should be recognised that beyond the immediate vicinity of existing cabins, there were most likely no new suitable sites. Local non-government stakeholders strongly believed that float cabin communities should be located in areas with existing float cabins. Hence position analysis suited their objectives. However, government stakeholders have a non-sectoral responsibility to satisfy the wider community that all possibilities and all users were considered. They noted that this procedure and resulting focus might inhibit them from meeting their mandate. This analysis does not necessarily reveal why stakeholders differ on positions, which is important to resolving any conflicts and disagreements. Participants can become entrenched in protecting their stated positions and encourage a tactical bargaining which does not promote a consensus decision process. In addition, due to the need to digitise participants' position maps it would not be possible to undertake position analysis at the table until technology developed more intuitive and user-friendly digitising techniques. Finally, it must be recognised that positions to locate float cabin communities in Barkley Sound is relatively simple to delineate compared to more comprehensive zoning strategies and thus may not be suitable in those types of processes.

Although the multi-criteria method is more easily undertaken at the table, there are several processing factors to consider. Depending on the number of criteria selected, hence number of overlays to manipulate, and the number of features contained in each map layer, the procedure can take a considerable amount of time and effort using today's technology. The interactive group analysis conducted in Workshop #1 and Workshop #2 took approximately 1 hour and

2 ½ hours respectively to process. Processing time can be reduced by incorporating a routine to eliminate polygon slivers after each overlay procedure, thereby reducing the number of polygon features to be processed. Alternatively, a raster-based overlay, which is technically more efficient than a vector overlay, can be used. This raises a common debate on the relevant suitability of vector and raster data structures both for analysis and the coast (Bartlett, 1994). Many GIS applications of multi-criteria analysis use raster structure. Raster structure also has appeal in representing continuous marine and coastal phenomena which do not lend themselves to vector boundary delineation. On the other hand spatial features such as float cabins are best represented as point data and the raster resolution required to represent float cabins would result in a vast increase in storage requirements. Thus, the debate continues.

A second factor is that this procedure is designed for polygonal data layers and because of the method used by GIS to overlay point or line data, these types of features cannot be directly incorporated. However, during the workshop the participants were not interested in discrete point and line features. Rather they applied a distance function from point features, such as archaeological sites, and line features, such as fish streams. The distance function was implemented using the buffer function thus converting the point and line features into polygon features consistent with the method of analysis. It is expected that this scale of analysis is suitable to most regional or strategic coastal management initiatives. Finally, leaving the method flexible to user-specified intervals and thresholds may prove to be a difficult task for participants, although this was not evaluated during the workshop. The task may be facilitated by adjusting values and comparing results until decision-makers are comfortable. At the same time it introduces the possibility of decision-makers manipulating the thresholds to influence the results in favour of their particular interest.

The difficulties experienced by the workshop participants in assigning compatibility indices and weights, and the approach chosen for the revised group analysis, suggest that the multi-criteria analysis would have benefited from a two-phased approach. An initial phase would identify all criteria which unequivocally exclude a particular activity for reasons such as safety, navigation, physical limitations and existing leases. These criteria would not be included in the weighting exercise since it is a binary assessment and there is no relative value to assign. The main advantage of this 'elimination' phase would be to reduce the problem domain and focus the exercise on criteria weighting. A second phase would consider areas which emerged as not excluded from a particular activity. Criteria for which there are varying degrees of suitability are then weighted in this analysis.

The multi-criteria analysis relies on stakeholders being able to identify explicitly their underlying interests by assigning weights. As mentioned earlier, this proved to be a difficult and somewhat 'meaningless' task for some participants. One participant was critical of the simplistic concept of weightings, noting that each person's weights come from different viewpoints or approach to the problem. The objective, however, is to explicitly incorporate the different viewpoints present around the decision-making table. Furthermore, the analysis is limited to decision criteria which can be expressed spatially and for which data are available. While the multi-criteria approach was generally endorsed by the participants, the concept of weighted multi-criteria was not so readily accepted. This is partly due to the weighting exercise being completed remotely prior to the workshop, without the benefit of discussion and explanation.

The fundamental large-scale, single-use planning issue of locating float cabin communities provides an efficient and manageable foundation for the initial development of a Coastal SDSS. However, it also raises the question of suitability for application of this process to more complex, small-scale, multiple-use strategic problems. In the least such an extension of the application would require potentially significant adaptations. With respect to scale such adaptations include data requirements, the size and membership of the decision-making group, and their familiarity with the issues and ability to contribute local knowledge. A multiple-use issue would certainly complicate the evaluation and assignment of weights extending from a single-dimensional matrix to a multi-dimensional matrix. Finally, a planning problem to site a certain activity is more confined and constrained in terms of potential alternatives than a strategic process.

Coastal Managers' Toolbox

One of the objectives of this research was to develop a catalogue of analytical techniques used for multiple-use coastal management and to assess the suitability of GIS to support these techniques with the intent of identifying a suite of tools that could be incorporated in a Coastal SDSS. Information on techniques was sought from the literature and questionnaires of coastal decision-makers. This proved to be a notably difficult task primarily due to the wide array of initiatives undertaken, the wide array of approaches adopted in coastal management, and the lack of descriptions on specific methodologies. However, based on the information acquired from the questionnaires and the literature, techniques can be broadly divided into three categories: Impact assessment; Multiple criteria; and Spatial assessment (Table 11).

Table 11: Techniques used in multiple-use coastal management

Impact assessment	Multiple criteria	Spatial assessment
•Ecological/Environmental •Economic •Social •Cost-benefit •Compatibility matrices	•Multi-objective programming •Multi-attribute trade-off analysis •Multi-attribute utility measurements •Weighted multi-criteria	•Delineation of homogeneous units •Spatial coincidences of uses •Weighted map combination •Areal comparison of alternatives •Siting suitability

The spatial assessment techniques described are mostly variations on the spatial overlay and query for unique conditions. They can be incorporated directly in GIS using available generic GIS functionality. The remaining techniques described, namely impact assessment and multiple criteria, have been applied in non-spatial contexts. Spatial equivalents of impact assessment and multi-criteria analysis have been implemented in other applications using GIS (Eastman *et al.*, 1995; Jankowski, 1995). These have focused on applying these techniques to spatial elements primarily as associated attributes. Further discussion on the coastal managers' tool box is presented in Section 7.

This section concludes the second of three SDSS components. Section 6 addresses the third component: data.

6.0 DATA

6.1 INTRODUCTION

This section focuses on the third set of research questions by reporting on the third component of a decision support system, namely the data which 'fuel' the system. Section 6.2 discusses data issues in coastal management, namely the importance of information, inventory content and communication. Section 6.3 addresses the specific issue of data quality including its perceived importance for coastal management, its association with GIS, and methods for evaluating and reporting data quality. Section 6.4 discusses the use of GIS in an inventory capacity and decision-makers' expectations of such a role. Section 6.5 concludes with a discussion on the implications of the findings with respect to a coastal spatial decision support system (Coastal SDSS).

6.2 DATA ISSUES IN COASTAL MANAGEMENT

Three data issues are discussed in this section, namely the importance placed on inventory by decision-makers, the type of information that is required for coastal management, and the emphasis on graphic communication.

Importance of Information

As was shown in Section 4.2, a third of Phase I respondents who reported critical success factors for coastal management decision-making identified data availability. This was second only to co-operation and commitment to the process. Data availability factors included:

- information sharing among participants;
- all participants having the same information;
- obtaining accurate data;
- obtaining up-to-date data; and
- providing technical and objective information to substantiate discussions, rather than basing in opinion.

Furthermore, in Phase II participants were asked to describe techniques and methods they would teach in a class for exploring alternatives. The majority of responses focused on information support topics rather than analytical topics. These included both general information support and specific information needs. Specific information needs will be discussed in Section 6.2. General information support topics were mentioned more often and included:

- the compilation of a comprehensive database which covers the broad range of natural and human elements;
- data acquisition techniques such as identifying information needs, identifying information sources, data availability and sampling techniques; and
- data management including the evaluation of database accuracy.

Inventory

The previous section identified that the compilation of a comprehensive database which accounts for the broad range of resources and users in the coastal environment is an important requirement for coastal management. The contents of such an inventory are well-covered in the literature (see for example, Harper *et al*, 1993; Hale, 1991; Ricketts, 1991) and have been reviewed previously in Section 2.5. The intent here is to present results from the research which will contribute to the development of an information taxonomy discussed in Section 7. Specific information needs raised can be organised expanded into seven inventory categories:

- Biological;
- Physical;
- Socio-demographic;
- Economic;
- Human use;
- Public perception, and
- Governance framework (Table 12).

Of interest is the importance placed on law, institution and policy as topics that should be taught. This supports the commonly held view that the governance framework comprising various government agencies and dispersed legislation presents a major impediment to integrated coastal management. Nevertheless, these elements are rarely incorporated in a coastal management inventory. The inventory list in Table 12 is by no means a comprehensive account of information needs for coastal management. Supplemented with the literature information presented in Section 2.5, it provides a framework of the taxonomy developed in Section 7.4.

Table 12: Preliminary information taxonomy for coastal management (Phase II)

CATEGORY	EXAMPLES
Biological	Coastal ecology Resources Habitat classification
Physical	Physical geography Tides and currents Hydrology Geology Sediment transport
Economic	Regional economic conditions Economic strategy
Socio-demographic	Quality of life Standard of living
Human use	Current use patterns Demands for future use

Public perception	Community values Community priorities
Governance framework	Regulation and legislation Jurisdiction and mandate Common law and private rights

Graphic Communication

Twenty-five percent of respondents who reported critical success factors for a successful outcome to coastal management decision-making identified effective communication of information and results as a success factor. 'Effective' was characterised as "understandable", "easy to read" and "consistent". In most cases maps were identified as the most effective and efficient format by which to convey information and results, such as defining areas of conflict, delineating proposed alternatives and presenting information to the general public.

The importance of information communication also was exemplified in the VI CORE process. On one occasion during the process, participants were given a report containing 30 maps and summary areal calculations on various indicator themes. Several interviewees noted that participants were unsure of how to interpret the information or to digest its quantity. In another example, the production of maps provided a negative focus on the process. As one participant commented "every time a map went on the wall people went berserk". The presentation of a map caused participants to narrow in on specific areas of the map on which they disagreed. As a result, discussions stalled on areas of conflict rather than progressed on areas of agreement.

6.3 DATA QUALITY

Importance of Data Quality

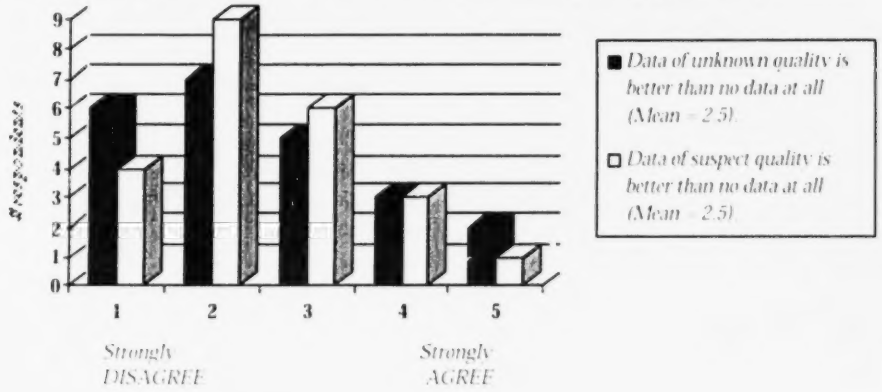
The importance of data quality for coastal management was raised by VI CORE interviewees, questionnaire respondents, and Barkley Sound Workshop participants. However, with the exception of the workshops, data quality was not a pervasive consideration.

Within the VI CORE process, issues such as decision-making process and data overload generally over-shadowed the issue of data quality. For example, conflicting data from different data sources and lack of solid information were mentioned as general, though not over-riding, impediments to the CORE process. Jackson (1997) undertook a more detailed study of consensus resource management processes in British Columbia. Her study revealed that solid information was important to the success of a consensus process. Nevertheless, it was recognised that solid information is but one factor in the process and a lack of solid information should not necessarily impede the process. Fewer interviewees in her study reported that lack of solid information did in fact stall the process. The need for solid information was tempered by the tendency to focus on numbers and data rather than the interests, and to overload the process with excessively detailed information. Several people also recognised that information provided to a decision process must be qualified with assessments of limitations and validity of the data, even if these assessments are 'just a best guess'.

Data quality was not a prominent issue raised by questionnaire respondents. Of those who identified data availability as a critical success factor for coastal management in Phase I, only three qualified it with the need for accurate and up-to-date information, and the need to be confident in the accuracy of the data. Data quality was raised by four respondents as a data management topic to be covered in teaching the exploration of alternatives. As one respondent noted, it is necessary to recognise "the limits of the database so as to realise that data may or may not be useful in decision making". When specifically prompted, 82% of Phase II

respondents agreed, or strongly agreed, that any coastal management plan should have an indication of confidence based on confidence in the data. Participants in Phase II also were asked to compare their use of data of suspect or unknown quality (Figure 17). Although answers were variable, overall there was a slight tendency not to use data of either unknown quality or suspect quality.

Figure 17: Evaluation of data of unknown or suspect data quality (Phase II)



At the workshops, the issue of data quality, particularly missing data, misplaced features, and aged data received much attention. This was in part due to the familiarity of the participants with the area as all but two of the participants lived in the Barkley Sound region. Participants were, therefore, more able and ready to detect errors and inconsistencies in the database than those who did not have local knowledge. The emphasis of data quality and the need to improve the data for decision-making were raised by two-thirds of the participants during their evaluations.

GIS and Data Quality

The link between GIS and data quality was made by all research target groups. Again this relates to the availability of data and the quality of the data which in some cases were hard to separate.

In the VI CORE process, one interviewee indicated that GIS was useful to evaluate data quality by making evident data gaps. This was countered by another interviewee who noted that cases of erroneous data such as inconsistency between data sources and misaligned features were targeted to discredit the whole GIS database.

In the Phase I questionnaire, issues of data quality were raised by respondents as both strengths and weaknesses of GIS. Twelve respondents felt that GIS enhanced or ensured the accuracy, objectivity and integrity of data for decision-making. They were far outweighed by those who felt that lack of quality control and the presence of data gaps were GIS weaknesses. In addition, eight respondents raised the issue that GIS has the potential for 'smoke and mirrors' when it comes to manipulating data, displaying results and decision-making, thereby instilling a false sense of accuracy.

Data quality issues were more prominent in the Barkley Sound workshops than either the VI CORE process or the questionnaires. The data used in the Barkley Sound workshops were the same data in digital format as used and produced in hardcopy for the Barkley Sound Strategy. Twelve of the sixteen workshop participants reported that they had examined these hardcopy

maps from the Strategy. However, only three were able to identify features contained in the maps and only another two questioned the validity of the strategy based on the data. More objections were raised to using some of the data in their current form after the workshop. This is likely the result of time taken during the workshop to explore the dataset at a level of detail and scrutiny previously not afforded. It is also possible that using GIS heightened their awareness of the quality of the data through the ability to interactively explore the data. By the end of the workshops, approximately two-thirds of participants noted that the major weakness of using GIS for decision-making was the lack of quality information. Unlike the VI CORE process, errors noted in the database were not seen to be a cause to discredit the entire data set. Instead, they were seen as an opportunity to make corrections and directly improve and contribute to the validity of the data set.

Evaluating and Reporting Data Quality

The responsibility for evaluating data quality, the factors that should be taken into account, and the format in which a data quality evaluation should be presented were investigated in Phase II of the questionnaire. These issues also were raised during the VI CORE interviews and the Barkley Sound workshops.

The responsibility to evaluate data quality is not placed squarely on either data collectors, data distributors or data users, but rather distributed among all three groups according to Phase II respondents. However, there is a slightly higher onus placed on data collectors.

Respondents were asked to rate the importance of various metadata components to coastal planning on a scale of 1 to 5 to give an indication of the factors which need to be considered in evaluating data quality (Table 13). None of the components presented was deemed to be unimportant. While the method of data collection was considered most important, other metadata associated with the data source: contact name of data collector, source reference and original intended use, were considered least important.

Table 13: Importance rating of metadata components based on a scale of 1-5, 5 most important (Phase II):

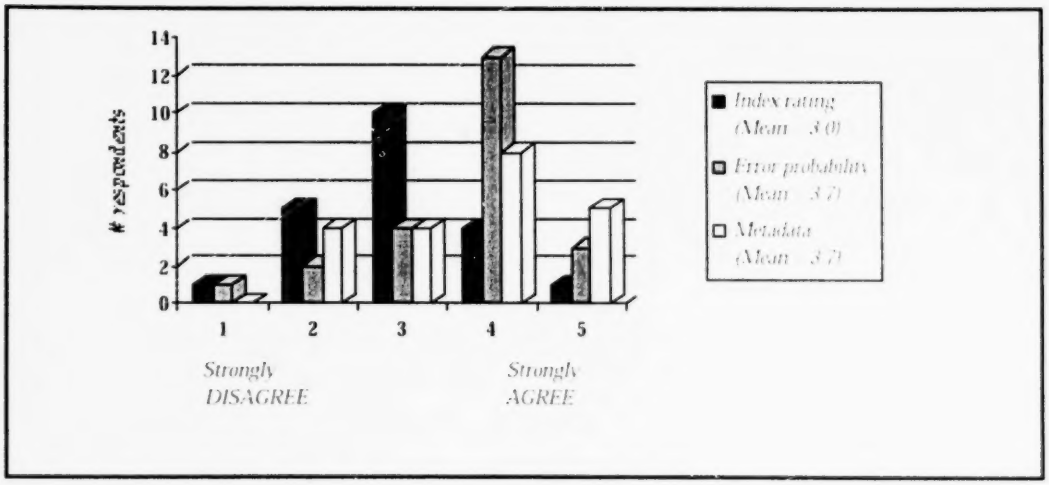
IMPORTANCE RATING	METADATA COMPONENT
Very Important (Mean (4.5)	Method of data collection Scale

Important (Mean 3.5 - 4.5) (in order of importance from most important)	Resolution Accuracy of attribute data Seasonality/temporal variability Year data collected Explanation of classification Manipulation operations Probability of error Spatial data gaps Attribute data gaps Temporal data gaps Precision Map projection Contact name of data collector Data source Original intended use

A point raised in both the VI CORE interviews and the Barkley Sound workshops was the need to incorporate local knowledge to substantiate the quality of a GIS database. One respondent from CORE noted that data quality evaluation should be supported by anecdotal evidence. This is particularly relevant in community-based initiatives such as Barkley Sound in which most of the participants might live in the region and, therefore, be familiar with the history, environment, and use of the area. Factors raised during the Barkley Sound workshops by the participants to evaluate the quality of the database comprised the trustworthiness and bias of the source of the data, the age of the data and definitions of terms.

Three formats were presented to the questionnaire recipients to report data quality, namely an index rating (such as high, medium, or low), a probability estimate of error, and a catalogue of characteristics of the data (metadata). Respondents were equally favourable to reporting a probability estimate of error and a metadata catalogue (Figure 18). However, one respondent indicated that a probability estimate of error would be too confusing for 'non-math' types. Several respondents mentioned that a catalogue of information should be available on request, such that all users are able to evaluate data quality. Seventy-five percent of respondents agreed or strongly agreed that data quality should be linked to each data layer, and one suggested that data quality should be linked to each individual data feature.

Figure 18: Format for reporting data quality (Phase II)



6.4 USE OF GIS FOR INVENTORY

Inventory Role of GIS

As was discussed above, the primary role for GIS in coastal management most often mentioned in Phase I was inventory. Inventory functions of GIS mentioned included storing and displaying an integrated inventory, and to a lesser degree facilitating information sharing. The role of GIS in these capacities was raised repeatedly during other parts of the questionnaire. For example, inventory characteristics, such as data integration, graphic display and communication, and data accessibility, of GIS were identified as strengths of GIS related to analysis and decision-making.

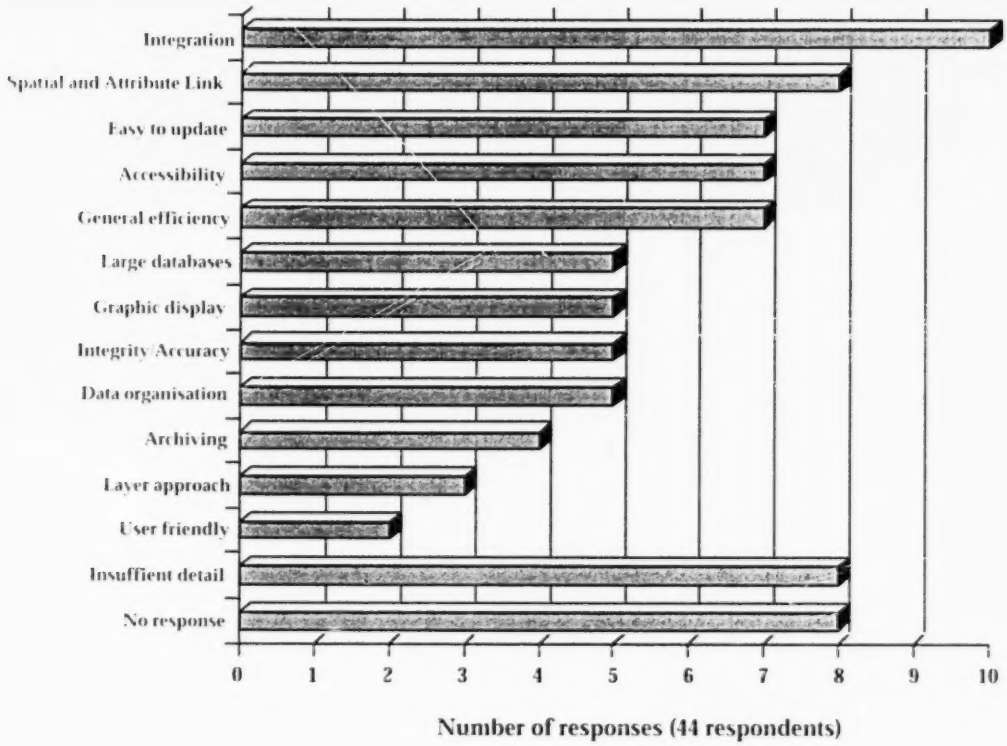
The inventory function of GIS to display and query data was used extensively in the Barkley Sound workshops. The first exercise involved exploration of the database through display and query using ArcView™ projected on a screen at the front of the room. A GIS analyst displayed and queried features as directed by the participants. During the exercise to explore alternative scenarios for float cabin communities, participants in both workshops relied almost exclusively on the interactive display and query. At the culmination of the first workshop a large sheet of paper was taped over the ArcView™ projection on the wall. Participants then marked on the sheet those float cabins identified for relocation or potential relocation, and areas which could accommodate further cabins. In other words, participants began to interact with the GIS database, although in a somewhat unconventional manner. The ability for intuitive onscreen annotation and feature editing may hay have facilitated this exercise.

Strengths of GIS for Coastal Inventory

The main strength of GIS with respect to managing and maintaining a coastal inventory identified by Phase I respondents is the ability to integrate a variety of data sets into common information base (Figure 19). The geographical context was seen to provide a common denominator for disparate data sets. A single source and multi-layered organisation was

regarded as important to facilitate the accessibility and efficiency of storing and retrieving large volumes of data.

Figure 19: Strengths of GIS for coastal management inventory (Phase I)



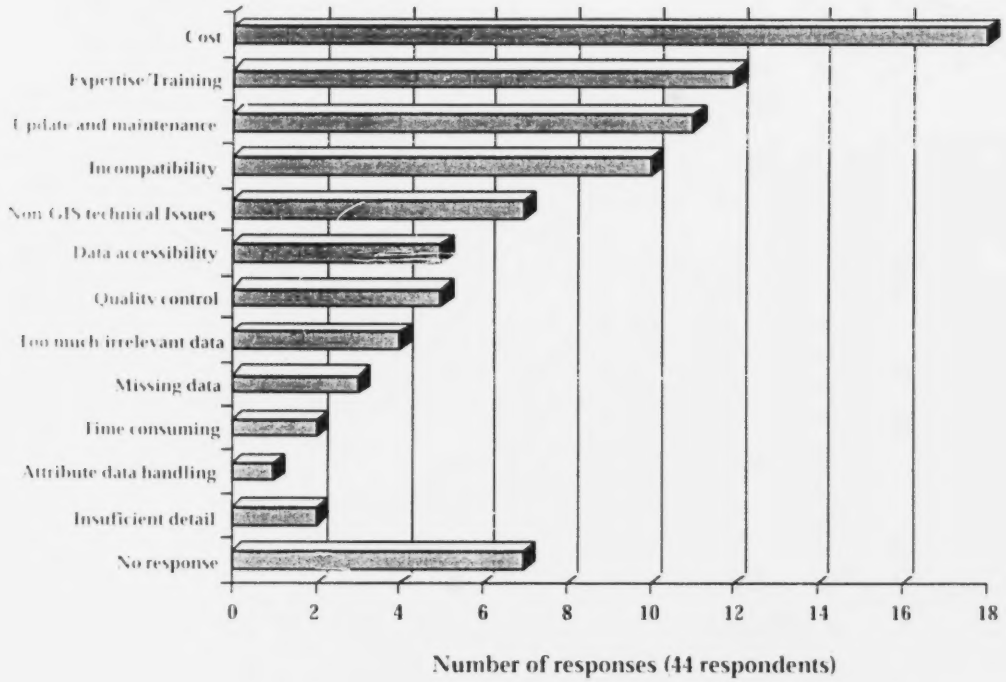
From the Barkley Sound workshops a third of the participants commented on the mapping capabilities of GIS as a strength. This strength was highlighted by the use of a projection system in conjunction with GIS which allowed all participants to view a map without crowding around a paper map. Mapping capabilities were facilitated by the interactive ability to zoom in and out, and to add or remove data layers at participants' request depending on the focus of the discussion. One member of the VI CORE process commented that the process may have benefited from the overhead projection of GIS maps. However, another countered the argument saying that "participants would still want hardcopy as this is what they're used to". It is interesting to note that those who specifically identified the graphic capabilities of GIS as a strength in the Barkley Sound workshops were participants in the first workshop in which it was used more extensively. The participants of the second workshop primarily identified the efficiency of GIS in manipulating data. It is unclear from the responses whether data 'manipulation' refers to the graphic manipulation or analytical manipulation.

Weaknesses of GIS for Coastal Inventory

By far the most often-mentioned weakness of GIS with respect to managing and maintaining an inventory of coastal data was the cost involved in acquiring and inputting the data. As with weaknesses of its analytical use, the expertise and training required also applied to its inventory use. On the one hand, some respondents noted that data stored in GIS were easier to update than data stored in paper map (see Figure 20). On the other hand, it was also noted that the requirement to continually update the data was seen as a weakness of GIS in terms of the time, cost and effort involved in maintaining a current database. In addition, incompatibility among GIS systems, data formats and data exchange procedures hindered the acquisition of an inventory.

Weaknesses of a GIS inventory emerging from the Barkley Sound workshops and VI CORE process were discussed earlier, namely data quality in the former and data overload in the latter.

Figure 20: Weaknesses of GIS for coastal management inventory (Phase I)



6.5 DISCUSSION AND SUMMARY

It is clear from the findings that inventory should be an important function of Coastal SDSS both in terms of the manner in which data are maintained and, more importantly, the manner of communication. In particular, attention was focused on the ease with which GIS output, whether hardcopy or softcopy (screen), can overwhelm decision-makers to the detriment of its communication goal. With respect to inventory content, the findings indicate that public perception and local knowledge, and the administrative framework of coastal management, somehow should be included in the inventory.

It appears that the issue of data quality becomes one of striking a balance within a spectrum of data abundance and data quality. The ideal situation is one in which there is sufficient good quality data. This situation is rarely achieved due to financial, time and availability constraints. More often, decision-makers are faced with a situation of limited but good quality data, or an abundance of poor quality data, or data that do not meet the needs of decision-makers. Decision-makers involved in this research exhibit two approaches to dealing with this situation. On the one hand some, such as the Barkley Sound workshop participants, advocated delaying a process until satisfactory data could be obtained. However, other comments, corroborated by Jackson's (1997) study, indicated that while decision-makers felt it was important to acquire the best available data, it was more important to be cognisant of the

reliability of the data. In some cases, the expectation of assessing data reliability is nothing more than a 'best guess'.

Although data quality was not raised as a significant issue in coastal management itself, it was raised more prominently when associated with GIS. There are two issues raised by the respondents. Firstly, one might consider whether decision-makers perceive that more accurate data would be required if GIS are used than if they are not used. Alternatively, GIS enable the user to more easily use data of poor quality while giving the perception of being more accurate. Alternatively, one can consider that decision-makers in fact think that good quality data are desirable in decision-making regardless of whether GIS is used, but that GIS heighten awareness of data quality as was apparent in the Barkley Sound workshops.

GIS are designed to contain spatial information. All other descriptive information is maintained as attributes of a given feature. In developing Coastal SDSS, one must consider whether GIS data structures are suitable for coastal data. Fixed structures and features which are relatively static and well defined, such as aquaculture leases and administrative boundaries and estuaries are easily represented as a spatial feature. Other features such as migration routes, currents, and the coastline itself can be represented as linear or polygonal spatial features through methods of interpolation. Most other natural elements that occur on the coast, are either horizontally dynamic or vertically dynamic, and/or inherently variable, and not easily represented in GIS. The use of raster structures, rather than vector, provides some opportunities to represent such natural elements in GIS.

Phase I respondents provided only general comments on the strengths and weaknesses of GIS to manage and maintain a coastal inventory. No specific reference was made by any of the respondents to the unique characteristics of the coast described above. The only comment specific to coastal data referred to the large volumes of coastal data that are required. This leads to the conclusion that coastal data, or perhaps more precisely the way coastal management is approached, is similar to many other GIS applications and terrestrial based resource use management. Therefore, the development of new coastal data models for Coastal SDSS might be premature until there is a shift in approach to coastal management. Alternatively, the opportunity to develop appropriate coastal data models may be the impetus required for such a shift.

This section concludes the foundation of this research. The three components of Coastal SDSS, namely decision-making, analysis and data, have been investigated to address the first three groups of research questions. The fourth, and last, group of research questions addresses the integration of the above three components into Coastal SDSS, and the implementation of a Coastal SDSS in a group decision-making process.

7.0 TOWARDS A COASTAL SPATIAL DECISION SUPPORT SYSTEM

7.1 INTRODUCTION

The primary goal of this research was to develop a conceptual design of a Coastal Spatial Decision Support System (Coastal SDSS) for group-based multiple use management (see Section 1.3). The preceding three sections have presented results from the research related to three components of a Coastal SDSS, namely coastal management decision-making, analysis and data. This section assimilates the research results from the three components into a conceptual design. The conceptual design is presented through twenty-one implementation and technical specifications. The first section discusses implementation factors. In keeping with the research framework, the following three sections discuss technical specifications for decision-making, analysis and data components of a Coastal SDSS.

The development and success of a Coastal SDSS in a decision-making process will be influenced by the role ascribed to it. Therefore, prior to discussing design specifications the context within which the Coastal SDSS will be operated must be established. The generic role of a Coastal SDSS as advocated is to facilitate the choice process involved in balancing the demands placed on coastal resources and space. This includes choices on location of activities, extent of development, acceptable environmental impact, and trade-offs among resource conservation, economic gain and social well-being. Within this generic role of Coastal SDSS the research conducted for this study indicates that decision-makers do not regard a Coastal SDSS as having a central role in the coastal management process. However, it is also clear, from responses on success factors and expectations of GIS, that a Coastal SDSS does have a role to play in coastal management albeit a more conservative one than was envisaged at the onset of this research. The role of Coastal SDSS that emerges from the research is to provide, primarily, information, and, secondarily, analysis in a format which contributes to the exploration and evaluation of alternatives, and facilitation of the choice process. The actual decision-making is maintained in the hands of the decision-makers, making a Coastal SDSS distinct from a comparative expert system or knowledge-based system. Group Decision Support Systems (GDSS) developed in the business sector, are often implemented in such a manner that each participant usually directly operates a networked terminal. In contrast, the preferred format for implementation of a Coastal SDSS is such that decision-makers indirectly interact with the system through a mediator. The design specifications discussed below conform to this prospective role of a Coastal SDSS.

7.2 IMPLEMENTATION

Format

Current research is focused on developing fully-networked and integrated Collaborative Spatial Decision Support Systems (CSDSS) in which participants each have direct access to a system. This format requires considerable technical development in GIS to accommodate the flexibility and real-time requirements of group decision-making. Even if technology was advanced to such a stage, coastal managers surveyed throughout this research were not receptive to such an integrated system. They chose the least integrated format of

implementation, in which the system is operated away from the table, the results from which are brought to the table as paper maps. The research further indicates that the format in which Coastal SDSS are implemented must strike a balance between decision-makers' familiarity with the data and their analysis to assist problem solving, and undue emphasis on technology. While decision-makers need to be trained and educated in system capabilities, excessive focus on the Coastal SDSS can lead to the negative perception of a technology-driven process.

Implementing the system through a technical working group remote from the decision-makers distances the latter from familiarity with the data and their analysis, thereby promoting the 'black box' effect of computer wizardry. A fully-networked hands-on system would require decision-makers to take more extensive technical training, would make the process even more technically driven, and may place those who are more 'techno-phillic' at a perceived advantage. Finally, it has been suggested that the terminals themselves may represent physical barriers between participants. Given appropriate implementation measures, the best solution which provides this balance, meets the concerns of decision-makers, and can be accommodated with the current technology is a chauffeur-driven system. The chauffeured format directly exposes decision-makers to the data and analysis while not requiring extensive training in the software or hands-on interaction to distract from discussions and negotiation. The chauffeured format does not obviate the need for a technical working group. Tasks such as acquisition and input of data, customisation of the system and conducting of some extensive analysis would still be carried out by a technical working group.

It is desirable to have multi-tasking capabilities at the decision table either through a single or multiple platform. This would avoid the bottle-neck effect of GIS processing. While time consuming analysis is being conducted, other functions, such as data query and display, can be undertaken and the group is not faced with an incapacitated system until the processing ends. This format proved useful in the Barkley Sound workshops. While analytical iterations were being run by the technical analyst, the facilitator continued the decision process through the use of an additional terminal if needed. Therefore, the process was not stalled during analytical processing.

With respect to hardware peripherals, the projection capability was found to be one of the most useful functions in the Barkley Sound workshops. This allows all participants to view the same information without having to crowd around a paper map. The transition from hardcopy to softcopy output may necessitate a fundamental shift in decision-makers' approach to information format. Whereas overhead projection is valuable for dynamic discussion there is evidence, particularly from the VI CORE process, that decision-makers are more accustomed to paper maps. Therefore, the capability of rapid hardcopy output would be useful for intermediary or summary maps and for taking notes.

Specification 1: ***A coastal SDSS should be implemented in a chauffeur-driven format. This format is supported by current technological capabilities, the GIS experience of prospective participants, and, most importantly, the balance that is necessary between technically-driven processes and familiarity of participants with system capabilities.***

Role of Facilitator and Technical Staff

In a chauffeur-driven system, the role of non-stakeholder participant is very important for its effective implementation. There are three roles to consider: process facilitator; system facilitator; and GIS analyst. Many group decision processes are moderated by a facilitator. The process facilitator is experienced in group process skills such as negotiation, conflict resolution, group dynamics, and consensus procedures. The facilitator's job is to direct participants towards an agreeable outcome. The system facilitator and GIS analyst are the intermediaries or 'chauffeurs' between the stakeholder participants and the Coastal SDSS. A system facilitator directs both the system and the participants to work in concert. A system facilitator needs to be cognisant of opportunities in which GIS information and analysis could enhance the discussion or answer questions raised. In addition, a system facilitator can direct participants to use the system by thinking systematically and spatially in a GIS context at relevant junctures of discussion. It is important, therefore, that the system facilitator be directly and continually involved in the decision-making process. For fully incorporated Coastal SDSS, the process facilitator and system facilitator should ideally be the same person. A GIS analyst is required to manipulate the system, respond to participants' display requests and queries, and conduct analysis. In order for there to be a smooth transition between the group and the system, the GIS analyst must respond quickly and efficiently to participants' queries as the seamless 'hands' of the decision-makers. The separation of system facilitator and GIS analyst allows the facilitator to focus on the group without being encumbered by computer handling.

Specification 2: ***A process facilitator thoroughly familiar and experienced with GIS capabilities, and a GIS analyst can serve to conduct the chauffeur driven format of a Coastal SDSS.***

Group Size

For any group decision process, the number of participants can be an important factor. Too few participants may not represent all relevant interests. Too many participants may stall the process by a multitude of voices. The group size is even more relevant when using Coastal SDSS. In fielding queries and requests through the Coastal SDSS, the process is likely to become increasingly congested with increasing number of participants. This would be more evident when the Coastal SDSS is used in an interactive analytical capacity.

The number of participants involved in the workshops and the VI CORE process can be used as guidelines in identifying an appropriate group size. At the first and second workshops there were nine and eight participants respectively, which allowed each one adequate involvement with the system. The VI CORE process had at least fourteen representatives. It was deemed by the representatives interviewed to be too many at the table for effective use of GIS. Although it is impossible to recommend an ideal number of participants, given the variety of interests involved in different coastal management processes, the experiences of both the VI CORE process and the Barkley Sound workshop indicate that a ballpark number of participants appropriate for effective interaction with a Coastal SDSS might be in the range of six to ten.

Specification 3: ***The use of a Coastal SDSS must consider the number of participants involved in a decision-making process to minimise the likely enhancement of the bottle-neck effect of group decision-making.***

Customised Interface

A customised interface is one of the fundamental components of a DSS. Through familiar menus and tool bars, a customised interface for a Coastal SDSS allows access by non-technical users to the inventory, to analysis designed for the application, to those generic GIS capabilities most often used, and to information products. Although in the chauffeur-driven format, decision-makers normally would not access the system directly, it is expected that viewing a customised interface with familiar terminology as opposed to a series of commands would engender a sense of familiarity and further overcome any perceived technical barrier. In addition, an easy-to-use interface allows the chauffeur to focus on the manner in which the system can contribute to the decision-making process rather than on the mechanics of operating the system. Allowance should also be made for an experienced user and the GIS analyst at a decision-making process to bypass the menu options and access the full suite of GIS functions and commands not incorporated in the menu interface. In order to ensure maximum familiarity of decision-makers with the Coastal SDSS interface, the system should be developed in close consultation with the intended users. Currently, few commercially-available GIS support the capability to customise user interfaces, thereby severely curtailing the suitability of most commercially available GIS as a platform for Coastal SDSS.

The challenge for a Coastal SDSS is the development of an interface which can be used in a variety of coastal management applications. The variety of coastal management processes, the diverse issues involved, and the time involved in developing a Coastal SDSS would make customisation of GIS for Coastal SDSS impractical for some initiatives depending on the scale and continuity of the process. The aim, therefore, is to strive for a standardised Coastal SDSS interface which can be widely applied with minimum alteration to a variety of coastal management initiatives. The interface developed for the Barkley Sound workshops provides a basis for a Coastal SDSS interface. It can accommodate a variety of group sizes and the analysis developed can be applied to various processes. The only elements that would require further customisation are the inventory menu and the choices for selecting decision criteria, both of which are dependent on the data available in the database, and both of which can be tailored easily.

Specification 4: ***Coastal SDSS should be accessed through a customised menu interface developed in close consultation with intended users. This will provide user-friendly access to the system's functionality and increase the familiarity between decision-makers and Coastal SDSS.***

Technical Accessibility

A Coastal SDSS must be technically accessible to the full spectrum of coastal management participants including the public, scientists, planners and political representatives such that all participants are equally advantaged by the technology. The perceived expertise required by decision-makers to use GIS is a significant barrier to overcome in the implementation of Coastal SDSS. This barrier can be overcome by the format of implementation as discussed above, and by the education and training of users. Appropriate education and training will serve both to level the playing field among the participants who have varying degrees of familiarity and ease with the technology, and to achieve maximum benefit from the system. It is expected that the more users are knowledgeable of the technology, the more at ease they become, and the more likely they are to use it to its potential.

The integration of education with the decision-making process, as opposed to a separate 'training day', has several advantages. It ensures that all members will participate and it also can produce immediate contributions to the decision process. A suitable time for such education would be after the participants, scope and objectives have been established, and data have been collected, but prior to the discussion of substantive issues. A one day meeting extending beyond demonstration, in which decision-makers actively participate, should be adequate to highlight two aspects of the system, namely data and analysis.

Data aspects should focus on both data availability and data quality through interactive exploration by the group. This allows the group to become familiar with and review the content of the database. Regarding data quality, participants can examine the accuracy of the data acquired and suitability for their process. At this stage data gaps can be identified, participants have the opportunity to suggest additional data requirements, and consensus can be sought on the acceptability of the data such that major data issues need not stall the process later on. With respect to analysis, it is important that participants be aware of system and GIS capabilities relevant to the application and, equally important, they must be aware of what the system and GIS are *not* capable of doing. An interactive review of the analytical models developed for the process, and generic GIS functions such as overlay and buffer, will assist the participants in gaining such an understanding.

Specification 5: ***At the onset of the process, a one-day educational workshop should be held. The workshop should be integrated with the process allowing participants to become familiar with and establish a uniform understanding of the data and analytical capabilities available.***

7.3 DECISION MAKING

Communication Role

The flexibility and efficiency of GIS graphic capabilities and its potential communication role in decision-making processes were identified prominently in the results from questionnaire respondents and workshop participants. Although the emphasis of most SDSS is in analytical functionality, the importance of graphic communication in itself as a decision support tool should not be underestimated. GIS approaches graphic communication from an analytical rather than a cartographic standpoint. Therefore many of the cartographic capabilities of graphics packages such as scaleable symbols and interactive graphic design are not incorporated in many GIS. In addition to flexible map design, a Coastal SDSS also requires the provision of different map types beyond the usual thematic maps. Particularly relevant to coastal decision-making is the efficient production of delta maps to compare two or more planning alternatives and consensus maps to track the areas of agreement among participants. For example, the choice of colour and symbology is very important in communicating an immediate message on the display, particularly in presenting results from analysis as discussed in Section 7.4. Further cartographic specifications are discussed relative to coastal inventory in Section 7.5.

Specification 6: ***The communication role of a Coastal SDSS should be emphasised in its development and implementation, particularly through displays tailored for decision-making rather than analysis.***

Generation and Evaluation of Alternatives

The primary decision-making approach used in most coastal management processes which emerged from the Phase I Questionnaire and supported in the wider field of resource management is the generation and evaluation of alternatives. Therefore, the decision-making process which is embodied in a Coastal SDSS should surround this approach. As such, there are two factors to consider. Firstly, there appears to be a dichotomy in the decision-making process forcing a balancing act between providing structure to the decision-making process through analytical support, and being sufficiently unregimented to allow for brainstorming and free flow of ideas. This balancing act is most important for the generation of alternatives. Opportunities for both structured and unstructured exploration should be incorporated in a Coastal SDSS. This means that alternatives should be able to be generated by manipulating or altering pre-defined parameters. They also should be capable of being generated 'on-the-fly' through interactive, on-screen delineation and definition. Interactive exploration need not require additional functionality. As was shown in the Barkley Sound workshops, simply the opportunity and ease to display and query the database can highlight some infeasible options or reveal new possibilities. Secondly, with respect to evaluation of alternatives, this should

include the ability to establish and define evaluative criteria which can be easily assessed. Specifications with respect to generating and evaluating alternatives are addressed below.

Specification 7: ***A Coastal SDSS should be based on the approach of generating alternatives, both analytically and 'on-the-fly', and of easily evaluating alternatives based on user-specified criteria.***

Dynamic Decision Making

The approach of generating and evaluating alternatives is not a linear process but rather an iterative one. The evaluation of alternatives may spawn new ones which in turn are evaluated. In addition, processes that involve a group of decision-makers are unpredictable given the uncertainties of how participants might react to others ideas and disagreements. In short, group decision-making is necessarily a dynamic, evolving and interactive process, one which cannot be constrained to deterministic decision-making models. A Coastal SDSS, therefore, must also need to accommodate the dynamic nature of group decision-making by responding to and promoting the flow of discussion leading to problem solving. Although it may be perceived as self-contradicting, as with any computer system development, the system flexibility which could accommodate dynamic decision-making must be anticipated and pre-programmed into the system. The system cannot be designed so rigidly that decision-makers must conform to certain pre-defined and structured paths of problem-solving and thought. This involves flexibility of the customised interface to be automatically updated as new information layers are created during the process, flexibility in terms of editing as seen in the subsequent section on data quality, flexibility to identify and calculate criteria for the generation and evaluation of alternatives, and flexibility of data capture from the screen projection. Accommodating real-time dynamic decision-making is one of the most challenging specifications with respect to Coastal SDSS development.

Specification 8: ***Coastal SDSS must accommodate the dynamic and unpredictable nature of group decision-making by programming flexibility.***

Anonymity

The accommodation of participant anonymity is one factor frequently raised when developing GDSS. Anonymity often encourages participants to raise ideas, interests and positions without fear of reprisal. The need for and benefits of anonymity depend on group dynamics and commitment to consensus-building engendered by the issues and process. Maintaining anonymity is not always a concern of participants. It was not during the Barkley Sound workshops. Nevertheless, the choice for anonymity should be designed into a Coastal SDSS. The pilot system developed for the Barkley Sound workshops preserved anonymity by assigning a code to each participant. Any map displayed, reports presented, or analysis conducted ascribed stakeholder information to the code and not specifically to a participant. However, the use of substitute codes does not necessarily preserve the identity of participants as the positions and criteria values can make the source blatantly obvious. Since the goal of consensus processes is to reach an outcome which is not necessarily unacceptable to any participant, it is often not necessary to reveal individual's positions or interests. Rather efforts should focus on the group's position and interests as a whole to which each participant has contributed. Therefore, anonymity is best preserved by the method in which individuals' positions and values are consolidated. Again, this does not necessarily guarantee anonymity.

Specification 9: ***The option of anonymity should be accommodated in a Coastal SDSS by using substitute codes and by focusing on the group's position and interests rather than those of individuals.***

7.4 ANALYSIS

Despite the general lack of emphasis on the analytical component of coastal management evidenced in the responses to this study, there were sufficient calls for innovative problem-solving, problem-solving skills and more rigour in decision-making to warrant attention. In meeting these demands, a balance must be struck between technical analysis and qualitative assessment to avoid the perception of a technology-driven process which excludes non-spatial criteria and human judgement, as cautioned by numerous study participants. The form of analytical support from a Coastal SDSS can be divided into that conducted at the table with the decision-makers and that conducted away from the table by a technical working group, the results from which are brought to the table. In order for analysis to be conducted at the table, it must be sufficiently compact in terms of input required and processing time, and must be capable of being repeated easily with slight variations to suit 'what-if' exploration. The overall goals of these analytical functions are to contribute to round table discussions and encourage new avenues of pursuit. This was emphasised in the analytical specifications developed for the Barkley Sound workshops and are represented by the first five specifications. The decision-making process may also require more extensive problem-specific one-time modelling, particularly in the area of environmental impact assessment. Finally, in addition to customised analysis, access to the full suite of GIS functionality should be included. All are described below.

Capability Analysis

Resources are subject to constraints and conditions such as food availability, substrate, water quality, and temperature which influence their distribution. The distribution of these resources in turn influence the environment's capability to support certain activities such as sport fishing, whale watching, and shellfish harvesting. The distribution of activities are also constrained by the physical environment such as deep water for port facilities and adequate current for waste discharge. In addition, the location of activities can be limited by other activities, for example a log storage lease precludes other activities from using that space. The combined distribution of resources, physical environment characteristics, and other users determine the areas capable of accommodating certain activities. Such assessment is termed capability analysis, and is often the first level of assessment in developing multiple-use management schemes. Prior to assessing areas of conflict, one must know the feasible areas under consideration. Capability analysis does not include any preference judgement at this stage, but is based on binary constraints of presence or absence. For example, in the case of the float cabin communities, capability analysis would include factors such as sheltered water, minimum size to accommodate a minimum number of cabins, and existing leases or reserved areas such as the national park, all of which are essential to determining where float cabin communities can be located. In so doing, capability analysis is the first effort to explore and reduce the range of alternatives to be evaluated for a management scheme

GIS are already used extensively for conducting capability analysis. Incorporating this type of analysis into a Coastal SDSS would require a menu interface to select resource, physical and other user themes, and attribute values which are both positive and negative constraints for a given activity. The results can be presented as a binary distribution map of capable and incapable areas for accommodating that activity.

Specification 10: ***Capability analysis which takes into account constraints and conditions influencing the location of activities should be the first level of assessment to identify feasible locations for certain activities. This would initially reduce the scope of alternatives to consider.***

Spatial Coincidence

The most fundamental analytical function to include in a Coastal SDSS for multiple use management is spatial coincidence to compare the spatial distribution of two or more resources or activities. Areas of overlap thus can be identified as potential spatial conflict. This can include comparison of current use or potential use based on the results of the capability analysis. It is important to note in such analysis that spatial coincidence is only a measure of *potential* conflict. Depending on the resources or activities under consideration they can overlap in spatial distribution and be either compatibly related or not interact at all because of seaonality or other temporal scales. In addition, features in GIS are primarily mapped in two dimensions while the marine component of the coast is a three-dimensional environment. Spatial coincidence assessed on a two-dimensional plane may not necessarily indicate interaction in a three-dimensional environment. Despite these caveats, this analysis can provide an initial perspective on potential conflict. It can be invoked using a simple overlay function available in all GIS and thus has the advantage of being one of the most familiar GIS analytical function to coastal managers in addition to being intuitively appealing.

Specification 11: ***Spatial coincidence, which considers temporal and three-dimensional scales, should be included in Coastal SDSS to give a preliminary account of areas of potential conflict among the environment and users.***

Multi-criteria Analysis

While capability analysis is based on binary criteria as the first effort to explore alternatives, multi-criteria analysis includes preference-based criteria to explore alternatives in more detail. The assumption is that decision-makers will differ on the degree of preference placed on these criteria according to their interests, and the objective is to achieve a solution which minimises these differences. While the criteria in capability analysis determine the *feasibility* of an area to accommodate a certain activity, the criteria in multi-criteria analysis modify the *suitability* of areas deemed capable of supporting a certain activity or group of activities. For example, scenery is not an essential criterion in determining feasible locations for float cabin communities but it would modify the suitability of an area. It is expected that different stakeholders will place different emphasis on scenery. Thus it is necessary to capture the preferences of each stakeholder for each criterion. In addition, it may not only be sufficient to capture stakeholder values for a criterion as represented by a data theme, as was used in the Barkley Sound pilot, but in some cases the attribute value or class will modify preferences. Parameters of the multi-criteria models to be manipulated include: 1) the criteria to include in the analysis; 2) the attribute value or class of criteria; and 3) the preference value. Thereby, multi-criteria analysis can provide a framework for systematic and structured exploration of alternatives. This can complement subjective and qualitative approaches such as brain-storming and 'on-the-fly' interactive editing. At the same time it includes subjective elements of stakeholders' values.

Within Coastal SDSS, the multi-criteria analysis must provide for user-specified criteria from a list of available data, and where relevant, attribute classes may also be selected as criteria. These can be managed by extracting all features of a selected attribute class into a separate data layer for manipulation. One of the key components of this analysis is capturing stakeholders' values. Considerable research has been undertaken in this area and there are numerous software packages designed to elicit such information from participants. The importance lies in capturing stakeholder preferences in a manner which is meaningful to decision-makers, results in values which actually represent their interests, and can be manipulated mathematically. The incorporation of multi-criteria analysis in GIS has received some attention among researchers (see Section 2.5) and is generally manipulated in a weighted overlay in either vector or raster format. There are two avenues that could be pursued. Multi-criteria analysis can be programmed *de novo* and incorporated with GIS using Application Programming Interface (API). Alternatively, existing multi-criteria software could be accessed through a Coastal SDSS interface and the preference values captured could then be incorporated in the GIS. The second approach takes advantage of available technology avoiding the need to 're-invent' the wheel while providing greater flexibility to capture stakeholder preferences.

Specification 12: ***Multi-criteria analysis should be incorporated in Coastal SDSS as a second tier of analysis to systematically generate alternatives. This analysis would facilitate exploration of alternatives according to preferences of criteria which modify the suitability of an area to support certain activities or groups of activities.***

Consensus Evaluation

The goal, although not always explicit, of group decision-making processes is to minimise differences and to achieve a collective agreement among the participants. As such, it is necessary to be able to evaluate the degree of agreement (and disagreement) among the participants regarding the alternatives generated. The format of consensus evaluation will vary depending on the specific decision objective. For example, in the case of the Barkley Sound workshop, the decision objective was to locate float cabin communities. As was shown with the position analysis, by overlaying each participant's preferred locations for communities, the group's areas of preferences and degree of commonality can be identified. Consensus evaluation in this example was simplified by the presence of *de facto* communities and consideration of only those areas with existing cabins thus limiting the scope of alternatives. The problem is made more complex when the objective is the development of a multiple-use strategy involving a variety of zones. In this case consensus is sought not only on the location of zones as in the float cabin example, but also on the zone designation. An alternative approach is to focus not on spatial consensus but rather on the level of agreement on the underlying interests as represented in the multi-criteria analysis. In the analytical example presented in this research, this requires evaluation of compatibility indices and magnitude of interest value. There are measures of quantitative disparity (see for example Bryson *et al.*, 1994 and Madu, 1994). Once differences in the underlying interest are addressed, the level of spatial consensus is expected to increase accordingly as the spatial alternatives are derived from the interest values.

Specification 13: ***A methodology is required to evaluate spatial and interest-based consensus according to the complexity of the decision problem***

Alternative Evaluation

The evaluation of alternatives is the second thrust in the decision-making approach after exploration of alternatives. Within a Coastal SDSS this includes spatially comparing alternatives and evaluating them based on pre-defined criteria. GIS are most suitable to represent evaluative criteria based on spatial measurements such as area, distance, proximity, direction and continuity and on attributes which can be assessed based on these spatial measurements. It is likely though, that not all evaluative criteria will be relevant to spatial measurements such as assessing the socio-economic impact of alternatives and some environmental parameters. Therefore, this will require integration with other models to evaluate alternatives, the results of which can be brought into the Coastal SDSS for tabular reporting and, where appropriate, for spatial reporting. In addition to being able to communicate each alternative through tables and maps, a methodology is required to represent and compare two or more alternatives both spatially and non-spatially.

Specification 14: ***Coastal SDSS must be able to evaluate alternatives and this should include spatial as well as non-spatial criteria (incorporated from external models).***

Environmental Modelling

Environmental interests and impact assessment figured prominently in the results of this research and should be incorporated in a Coastal SDSS. Given the dynamic medium of the coastal environment, this implicitly requires consideration of coastal process modelling although this was not raised specifically by those participating in this study. This is perhaps indicative of the predominant trend to transpose land-based planning technology and procedures from terrestrial-based environments to coastal environments. Without the incorporation of coastal process modelling, particularly with respect to environmental implications, the use of GIS in the coastal planning regime will prove to be limited. Considerable work has been undertaken in the development of coastal process modelling with advances in three-dimensional and temporal GIS which can be incorporated. In addition to technical considerations, the inclusion of these models requires that the explicit link between environmental impact assessment and process modelling be recognised by decision-makers.

Specification 15: ***Environmental modelling provides necessary input to environmental impact assessment, and its incorporation in a Coastal SDSS requires advances in three-dimensional and temporal GIS and recognition of this link by decision-makers.***

Generic GIS Functionality

The analyses described thus far in Section 7.4. are aimed directly to suit the decision-making process and participants. Invariably, it is impossible to anticipate the questions that will be raised and analyses that will be required. Therefore, the analytical functionality of a Coastal SDSS should not be limited to the examples recommended above. Access to the full suite of GIS

functionality will allow the capabilities of Coastal SDSS to be augmented during the process as the need arises.

Specification 16: ***The full suite of GIS functions should be accessible to Coastal SDSS users to augment customised analysis.***

7.5 DATA

Taxonomy of Coastal Inventory

The types of information used in multiple-use coastal management vary greatly among the initiatives due to differences in scope and local emphasis. The development of a data taxonomy for coastal management would provide a framework for data gathering and organisation and a useful standardisation for comparison. Taxonomic schemes have been developed for coastal morphology (Sherrin and Edwardson, 1995; Fricker and Forbes, 1988). However, a standard classification for systematically categorising human-use activities in the coastal zone relevant to multiple-use management has not been addressed (Harper *et al.*, 1993).

Based on a literature survey of comprehensive coastal management projects (see for example Harper *et al.* 1993; Hale, 1991; Ricketts, 1991), a taxonomy of coastal inventory was developed and is presented in Appendix C. The taxonomy is divided into three sections: 1) Natural Environment: resources and natural features; 2) Human Use: utilisation of those resources and features; and 3) Administration: management regime of the natural resources and their utilisation.

In developing the taxonomy, emphasis was placed on those features which have received relatively minimal attention, namely human use and administration, in order to facilitate the identification of potential conflicts among users, between users and the environment, and management structures. The taxonomy is intended to cover a broad spectrum and includes:

Human Use

- Demographics
- Biological resource extraction
- Mineral resource extraction
- Cultural resources
- Recreation and tourism
- Energy
- Industry and commerce
- Military
- Shipping, navigation and transportation
- Waste disposal

Administration

- Boundaries
- Government and agency responsibilities
- Legislation
- Tenure
- Community programs
- Special status areas

In addition, relevant examples in each category were identified. These examples are not intended to be comprehensive and will depend on the specific issues addressed and the scale of

each coastal management initiative. In order to adequately identify conflict susceptibility, degree of conflict and management, there are four characteristics of the natural environment and human use to consider, namely distribution, process, value and regulation. The organisation of the data according to the taxonomy laid out could be incorporated in a customised menu to facilitate access to the various data themes. Each menu item spawns a list of the available data themes within that category.

Specification 17: ***Continuing from taxonomies created for the natural environment, taxonomies of coastal use and administration need to be established.***

Jurisdiction

Jurisdictional fragmentation of the coastal zone is often cited as a major impediment to Integrated Coastal Management (ICM) causing competition among agencies or non-activity, depending on the resource and agency's response. One respondent in Phase I cited jurisdictional conflict as being the cause of a failed decision process. A clear spatial representation of jurisdictional responsibilities would be a valuable informational contribution to the coastal management process. This issue has rarely been addressed in a systematic manner. In British Columbia, initial efforts at jurisdictional mapping include the delineation of boundaries between internal waters and territorial seas (Dorcey, 1986), and differentiation between federal and provincial jurisdiction for some activities (Garner, 1990). A more in-depth geo-referencing of coastal zone legislation has not been undertaken for British Columbia (Greer, pers. com.). Schematic diagrams have been created to show legislative boundaries in the coastal region although these were not directly applied to a specific area (Goldin, 1993). To the knowledge of this researcher these types of schematic diagrams have not been incorporated into GIS as a meaningful information source for decision-makers.

Geo-referencing of jurisdictions requires an extensive review of current legislation which spans coastal areas. Such a review is sufficient material for another PhD, and is beyond the scope of this research. This pertains to legislation regarding the mandate of government agencies. For example, Day and Gamble (1990) reviewed the institutional setting of coastal management in British Columbia, identifying at least sixteen federal agencies, fifteen provincial agencies plus regional districts, municipalities and First Nations bands who have some form of responsibility. In some cases jurisdiction is assigned to a specific region of the coastal zone with spatially defined boundaries such as lower water mark or higher water mark. Jurisdiction may also vary on a vertical spatial plane such that, at a given location, one agency may be responsible for a specific resource in the water column while another agency may be responsible for resources in the seabed. Legislation would also have to be reviewed from the perspective of mandates over coastal resources and activities. Whereas some agencies focus on particular sectoral issues such as fisheries, others have wider mandates encompassing composite phenomena such as environment, water quality and safety at sea. In addition, there may exist jurisdictional anomalies that are applied in very localised areas which need to be considered.

There are two ways to portray jurisdictional information in GIS which satisfy both the spatial and sectoral allocation of jurisdiction. The spatial allocation of jurisdiction is most easily represented as a separate data layer. The intention is to be able to query a given location and

report the agencies and legislation which govern that area. The second approach would be to include jurisdiction as an attribute to each resource or human use data layer.

Specification 18: ***Spatial data layers that delineate administrative responsibilities must be included in Coastal SDSS to assist coastal managers clarify multi-agency jurisdictions.***

Continuous Terrain

Elevation models and bathymetric models generally each stop at the coastline. In addition, the coastline is often portrayed with a different configuration between the two models as they are based on different vertical data. For example, depth soundings from the Canadian Hydrographic Service (CHS) are established against Low Low Water (LLW) while elevation points from the Terrain Resource Inventory Mapping (TRIM) are established against Mean Sea Level (MSL). Therefore, depth soundings and elevation points are not established on a comparable scale. As a result, without expensive data collection, it is not easy to acquire a continuous representation of coastal terrain around the coastline, one of the most important regions of the coast.

Many coastal activities are primarily land based or marine based, with impacts which spread to adjoining environments. Float cabin development is primarily a marine-based activity requiring minimal foreshore access. However, it may conflict with adjacent upland ownership, uses and resources. Because the coastal zone is usually depicted in two distinct zones, land-based and marine, the influence of adjacent upland activity is not automatically noted.

A technique was sought to develop a continuous terrain model of the coastal zone using the most widely available data sets thereby avoiding the need for data collection. One possibility is to reconcile the difference in vertical datum and adjust either data set accordingly. This would require an establishment of a standardised coastline. However, by not reconciling the difference, it is possible to maintain the true representation of the lower intertidal zone as that dynamic region of the coast between LLW and MSL. The intermediate area between the two vertical data could then be maintained uniquely as a polygon representing the lower intertidal zone (Figure 21).

Figure 21: Diagram of continuous terrain for the coastal zone

There were several problems encountered in following this technique for the data available for Barkey Sound. Problems related primarily to the integration of data from different sources. The data sets used different horizontal data requiring a datum shift. In addition, the data were collected at different scales resulting in different levels of resolution and incomparable configurations. As a result of these discrepancies it was found that the two coastlines which theoretically should maintain landward/seaward relationship in fact criss-crossed over each other making the creation of an intertidal polygon not feasible as shown in Figure 22. Attempts were made to investigate this discrepancy between the two for horizontal and vertical patterns. Despite applying all legitimate spatial compensation techniques, such as datum shift, and rubber sheeting, the discrepancy was still evident. It was concluded that the discrepancy was the result of different resolution and accuracy. In general, bathymetric soundings are used for navigation and safety purposes and therefore have a higher degree of accuracy compared to elevation points. Nevertheless, efforts to reconcile the differences are being pursued by the CHS (Dave Jackson, pers. com.) and other agencies. Assuming that these discrepancies will be overcome eventually, the diagram presented in Figure 22 is a useful one for representing the coastal terrain as a continuous model while emphasising the important intertidal zone.

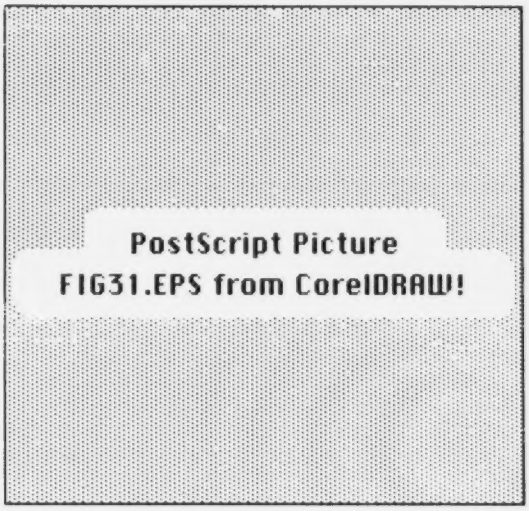
Specification 19: ***Management of the coast should be framed within a model of a continual environment in which the dynamic boundary of the transition zone between marine and terrestrial is represented.***

Graphic Communication

Although the graphic communication capabilities of GIS were cited repeatedly as one of its main strengths for decision-making, many would argue that GIS in fact do not excel in

cartographic production. There are two suggested functions which could increase the cartographic communication of GIS.

Figure 22: Example of discrepancy between elevation (TRIM) and bathymetric (CHS) vertical datum



The display of features in vector formats tends to impart a greater sense of definity in the location of boundaries than is warranted by the nature of the environment, particularly with respect to biological and hydrological features such as resource distribution and hydrodynamic processes. Therefore, the uncertainty and variability of the distributions of features should be reflected in their graphic representation, so that decision-makers do not place undue certainty to these features. Representation of uncertainty is a current theme in GIS research and should be applied in the development of Coastal SDSS (Davis and Keller, forthcoming; Lowell, 1993; Suryana, 1993; Fisher, 1991).

Coastal thematic atlases are often designed with icon symbology which instantly convey the distribution of coastal resources (Dickins *et al.*, 1990). Such flexibility is not generally incorporated in GIS although some packages do provide the capability to customise feature symbology. In addition to contributing to communication, customised symbology for point, line and polygon features can also be used to convey the variability and uncertainty in data discussed above. In addition, the use of multimedia technology incorporating satellite images as graphic background to vector data, video clips and narrative descriptions will enhance the ability of a Coastal SDSS as a communication tool.

Specification 20: ***Advances in GIS cartographic production such as representation of uncertainty and continuity, greater flexibility in customised symbology and the incorporation of multimedia technology are necessary for Coastal SDSS to fill their communication role.***

Data Quality

The importance of decision-makers being given adequate time to review the data available to them and, more importantly, to evaluate the validity of the data such that confidence can be gained, was evident during the workshops. Evaluating the data as a group at the onset of the Barkley Sound workshops through interactive exploration provided participants an opportunity to become familiar with the data, and to identify data gaps and errors. Such a process of group evaluation is particularly useful in that it taps into the local knowledge of the participants, knowledge otherwise undocumented. However, it must also be acknowledged that this process of data review and edit may introduce biases to the data set according to the knowledge and integrity of individuals at the table, and that this process does not necessarily negate the requirement of independent ground truthing. In order to record the corrections to the database, Coastal SDSS require the capability to efficiently and interactively edit the database, both spatial and attribute components, during group meetings. For example, you would need the ability to add missing features, delete erroneous or dated features, move misplaced features and alter attributes 'on-the-fly' as these data errors are noted. In addition to interactively changing the database, it should also be possible to record these changes as lineage metadata. Implementing this exercise in a decision-making process will depend on the scale of the initiative, quantity of data, and familiarity of participants with the area.

A strategy for managing and reporting data quality requires a balance between making information available which is useful to the decision-makers so that they can adequately consider the quality of the data, and providing that information in a format which allows for easy interpretation. The participants should not be overwhelmed with data quality information. A suitable metadata strategy for Coastal SDSS must be linked to individual thematic layers. A prototype metadata strategy was developed for the Barkley Sound workshops by creating two tables for each feature theme, and associated with the relevant data layer. The first table records metadata attributes which describe the current status of the database (Canessa and Keller, 1994). Because the amount of information is extensive, users should be able to select any of these metadata attributes for reporting. Data quality can thereby be assessed according to the user's requirements. The second table records the evolving lineage of the data layer . Because maintaining lineage is a continuous process through the life of a project, it is desirable to report lineage separately from other metadata attributes. Linking these tables to each feature as has been suggested would create much information redundancy. Therefore any changes to specific features can be recorded in the lineage table. A provision should be made which allows users to record the lineage of the data as editing and manipulations are conducted.

Specification 21: ***A metadata strategy for data quality should be incorporated in Coastal SDSS. Such a strategy should include the ability to record and continually maintain metadata attributes, to link data quality to each data layer, and to retrieve only those metadata attributes which are relevant.***

7.6 SUMMARY

This section has provided the initial ingredients for a Coastal SDSS 'recipe'. The recipe is founded on a role of Coastal SDSS that provides information and analysis to decision-makers. These are provided in a format which enables a group to explore and evaluate a range of

alternatives, facilitates the choice process involved, and allows the group to reach a collective outcome. The ingredients are presented as design and implementation specifications under the topics of: 1) implementation; 2) decision-making; 3) analysis; and data. These specifications are summarised in Table 14.

The crux of implementing Coastal SDSS is to balance the perception of a technology-driven process with decision-makers' familiarity with the system. A chauffeur-driven system operated by a GIS analyst at the table is one of the factors aimed at addressing this balance. In addition, the presence of a GIS facilitator versed in both group decision-making and GIS analysis can help to ensure that maximum benefit is obtained from a Coastal SDSS. A GIS facilitator can recognise opportunities where the Coastal SDSS can respond to particular queries, and can direct decision-makers to alternative avenues of thought. A third element which addresses the necessary balance mentioned above is appropriate education and training for the decision makers in the form of a one-day workshop which combines two equal objectives. The first objective is to introduce participants to functional and analytical capabilities of GIS. The second objective is to allow participants to become familiar with and to review, discuss and possibly edit data sources.

Table 14: Design and implementation specifications for Coastal SDSS

TOPIC	SPECIFICATIONS
Implementation	1. A Coastal SDSS should be implemented in a chauffeur-driven format. This format is supported by current technological capabilities, the GIS experience of prospective participants, and, most importantly, the balance that is necessary between technically-driven processes and familiarity of participants with system capabilities. 2. A chauffeur-driven format should be facilitated by a process facilitator thoroughly familiar and experienced with GIS capabilities, and a GIS analyst. 3. The use of a Coastal SDSS must consider the number of participants involved in a decision-making process to minimise the likely enhancement of the bottle-neck effect of group decision-making. 4. A Coastal SDSS should be accessed through a customised menu interface developed in close consultation with intended users. This will provide user-friendly access to the system's functionality and increase the familiarity between decision-makers and a Coastal SDSS. 5. At the onset of the process, a one-day educational workshop should be held. The workshop should be integrated with the process allowing participants to become familiar with and establish a uniform understanding of the data and analytical capabilities available.

Decision-making	6. The communication role of a Coastal SDSS should be emphasised in its development and implementation particularly through displays tailored for decision-making rather than analysis. 7. A Coastal SDSS should be based on the approach of generating alternatives both analytically and 'on-the-fly', and of easily evaluating alternatives based on user-specified criteria. 8. Coastal SDSS must accommodate the dynamic and unpredictable nature of group decision-making by programming flexibility. 9. The option of anonymity should be accommodated in a Coastal SDSS by using substitute codes and by focusing on the group's position and interests rather than those of individuals.

TOPIC	SPECIFICATIONS
Analysis	10. Capability analysis which takes into account constraints and conditions influencing the location of activities should be the first level of assessment to identify feasible locations for certain activities. This would initially reduce the scope of alternatives to consider. 11. Spatial coincidence, which considers temporal and three-dimensional scales, should be included in Coastal SDSS to give a preliminary account of areas of potential conflict among the environment and users. 12. Multi-criteria analysis should be incorporated in Coastal SDSS as a second tier of analysis to systematically generate alternatives. This analysis would facilitate exploration of alternatives according to preferences of criteria which modify the suitability of an area to support certain activities or groups of activities. 13. A methodology is required to evaluate spatial and interest-based consensus according to the complexity of the decision problem. 14. Coastal SDSS must be able to evaluate alternatives and this should include spatial as well as non-spatial criteria (incorporated from external models). 15. Environmental modelling provides necessary input to environmental impact assessment, and its incorporation in a Coastal SDSS requires advances in three-dimensional and temporal GIS and recognition of this link by decision-makers. 16. The full suite of GIS functions should be accessible to Coastal SDSS users to augment customised analysis.
Data	17. Continuing from taxonomies created for the natural environment, taxonomies of coastal use and administration need to be established. 18. Spatial data layers which delineate administrative responsibilities must be included in Coastal SDSS to assist coastal managers clarify multi-agency jurisdictions. 19. Management of the coast should be framed within a model of a continual environment in which the dynamic boundary of the transition zone between marine and terrestrial is represented. 20. Advances in GIS cartographic production such as representation of uncertainty and continuity, greater flexibility in customised symbology and the incorporation of multimedia technology are necessary for Coastal SDSS to fill their communication role. 21. A metadata strategy for data quality should be incorporated in Coastal SDSS. Such a strategy should include the ability to record and continually maintain metadata attributes, to link data quality to each data layer, and to retrieve only those metadata attributes which are relevant.

Undoubtedly, the primary contribution that a Coastal SDSS can make in decision-making is communication of information and ideas. This needs to be recognised when developing Coastal SDSS with respect to the types of maps that are produced, and the cartographic flexibility required to produce such maps. Neither of these capabilities is a noted strength of GIS. A balance is also required in the approach to generating and evaluating alternatives,

which is the primary decision-making process. On the one hand, there is a need for Coastal SDSS to integrate structured problem-solving models. However, these models should not be integrated at the expense of stifling the natural dynamic flow of group decision-making that comes from the iterative decision process and interaction of participants.

It has been established that the general decision-making approach is to generate and evaluate alternatives. A two-phased analytical approach is advocated. The aim of the first phase is to reduce the range of alternatives according to feasibility of activities. The second phase explores the suitability of these feasible alternatives using preference-based criteria. These criteria allow the values and interests of each participant to be take into account. The types of analytical support discussed combines customised analysis with existing, often non-spatial techniques, developed outside of GIS. Customised analysis, such as capability analysis and spatial coincidence, leans on the spatial models of GIS, primarily the overlay. However, there also exists a wealth of non-spatial techniques such as multi-criteria analysis, methods of evaluating alternatives, and environmental modelling which need to be brought into coastal management.

The last group of Coastal SDSS 'ingredients' discussed pertain to the data component. Data and inventory topics have received most attention in coastal management initiatives although there are still efforts required to consider data with a decision-making focus as opposed to an inventory or an analytical focus. These include a taxonomy of coastal use and administrative responsibilities with emphasis placed on spatially representing these responsibilities according to resource, activity and agency. Within the Coastal SDSS inventory, the coastal area should be considered as a continual transition zone between terrestrial and marine environments. This involves the development of a continuous terrain model which does not impose boundaries as the basis for all inventory collection and mapping. Various specifications are suggested to meet the communication role of Coastal GIS, namely representation of uncertainty, greater flexibility in cartographic production, and the incorporation of multi-media technology to enhance communication based on maps. Finally, any decision derived from an inventory is only as good as the inventory itself. A metadata management strategy distils data quality to its essential components allowing users to consider only those components which contribute to their assessment of suitability and relevance.

On a final note, the development and implementation of a Coastal SDSS is a multi-faceted challenge spanning numerous disciplines. Therefore, it is best accomplished by using a multi-disciplinary team whose individual expertise lie in coastal management, group decision-making, consensus building, computer science, environmental modelling, and GIS to name but a few.

8.0 CONCLUSION

8.1 INTRODUCTION

The coast is subject to increasing pressure from a multitude of often competing users. Coastal managers are faced with the challenge of balancing the distribution and activities of users while taking into account user conflicts, environmental impacts, socio-economic benefits, and the voices of the coastal community. On another stream, Geographic Information Systems (GIS) are being heralded as decision-support tools for a wide array of spatial planning problems. These tools range from inventory warehouses to dedicated spatial decision support systems (SDSS). The next generation of SDSS, Collaborate SDSS for decision-making groups, is on the horizon. This research investigated the marriage of these two fields, coastal management and GIS, through the development of a Coastal SDSS.

The research was pursued by exploring the component parts of a Coastal SDSS:

- the decision-makers and process within which they function;
- the analysis upon which decisions are made; and
- the data which are analysed and which themselves contribute to an understanding of the decision problem and solution.

Information and observations for each of these components were gathered from five sources:

1) literature survey;
2) a two-phased questionnaire of coastal decision-makers;
3) interviews of participants of a resource management multi-stakeholder process;
4) non-participant observation of a regional coastal management process; and
5) two workshops to implement and evaluate a pilot Coastal SDSS.

The results from all these sources were then assimilated into design and implementation specifications of a Coastal SDSS.

An additional method that could have been employed to gather information was an in-depth survey of coastal management case studies. This could have evolved into an exhaustive survey. Although such a survey could have provided valuable information, a preliminary review revealed that reported case studies generally did not provide the level of detail, with respect to methodology and decision-makers' expectations of GIS, desired for this research. It was, therefore, deemed more important to acquire information directly from coastal decision-makers. Although a response rate of approximately 30% was attained for both questionnaires, most respondents were from British Columbia which does not have a structured mechanism for coastal management. Thus, the results may be skewed to represent the British Columbian example of coastal management rather than more experienced examples. More respondents from the U.S., which has a longer established history in coastal management, could have compensated for this short coming. Each data collection method used in this research in itself does not target the full range of coastal decision-makers. However, combined, they included government agencies, scientists, academics, consultants and community stakeholders and adequately covered the breadth and detail of information sought.

This concluding section reflects on the research findings. It seeks to tie the research together and to offer a more general look towards a Coastal SDSS of the future. The research is reviewed in terms of the main findings (Section 8.2). Main findings are discussed in light of the originally stated primary objective of this research (Section 8.3). Finally, suggestions for further research conclude this section (Section 8.4).

8.2 SUMMARY OF FINDINGS

Decision Making

The first set of research questions addressed the decision-making requirements of a Coastal SDSS by investigating the process, tasks, and participants involved in coastal management and the expectations of decision-makers towards the use of GIS in a decision- making capacity. It was found that coastal decision-making varied in all three areas: process; tasks; and participants, although several observations can be made regarding each.

With respect to process, it was found that the *modus operandi* of coastal management is the generation and evaluation of alternatives within a broader process of strategic assessment. With respect to tasks, ten general tasks could be distilled from the varied responses:

1) define problem;
2) establish process;
3) collect data;
4) analyse and assess data;
5) synthesise results into draft strategy;
6) review draft;
7) revise strategy;
8) adopt strategy;
9) implement strategy; and
10) monitor implementation.

These ten tasks do not comprise a prescribed set of tasks for coastal management. In practice they may be re-ordered, or several of the tasks may be omitted, and there exist variations within each task.

With respect to participants of coastal management processes, it was discovered that government representatives lead the membership. There appears to be an inclination towards involvement of community stakeholders in varying capacities. More commonly, stakeholder involvement is through public consultation. To a lesser extent, community stakeholders may have direct participation in the decision-making process with an emphasis on consensus building. The importance of participants, not only who they are but also their approach to the process, was raised several times in the study. Most notably, co-operation and commitment brought to the decision-making table was raised as the most important success factor in coastal management.

The primary expectations raised by decision-makers of GIS in decision-making are inventory driven, both in terms of information management and communication. In addition, the ability to explore alternatives and to facilitate 'what-if' scenario building were recognised as important

contributions of GIS to decision-making. GIS were also seen as potential detractors of the decision-making process by overwhelming and seducing decision-makers, imposing a technological fix to the exclusion of human elements, and requiring prohibitive resources and expertise.

Analysis

The second set of research questions addressed the analytical requirements of Coastal SDSS by investigating:

- current analytical techniques used in coastal management;
- the suitability of GIS to facilitate existing techniques and their ability to prompt the development of new ones; and
- the expectation of decision-makers towards the use of GIS for analysis.

The responses received for analytical techniques to generate and evaluate alternatives can best be described as general and sparse. Various reasons are proposed for this outcome. First, there may be a lack of well-established analytical techniques to begin with. Second, the apparent *ad hoc* process may make it difficult to isolate specific techniques of a coastal manager's toolbox. Third, the decision-makers surveyed may be sufficiently removed from the analytical techniques of the decision-making process.

Nevertheless, three categories of techniques emerged from the responses:

1) impact assessment, particularly related to environmental modelling;
2) multiple criteria; and
3) spatial assessment.

A multiple criteria model was developed in this research. It was implemented in a pilot Coastal SDSS for the workshops. The multi-criteria model involved selecting a group of criteria stored as GIS data layers. These criteria included activities and resources which were either compatible or incompatible with locating a specific activity. The criteria were weighted according to each stakeholder's interests and combined to give a picture of potential alternatives. Although the theoretical basis for the model generally was supported by workshop participants, it was discovered that they required a greater degree of training in order to more fully understand and reap the benefits of this methodology.

Responses on analytical expectations of GIS echoed decision-making expectations. Responses were peppered with comments on inventory capabilities of GIS. Most notably, the efficiency of GIS to manipulate data was regarded as being particularly conducive to exploring potential solutions. The expertise required, technological fix advocated, and potential to seduce and bias decision-makers were seen as disadvantages of using GIS in an analytical capacity for coastal management.

There are three main conclusions to be drawn from these results. First of all, the expectations of decision-makers for GIS to fill an analytical role are over-shadowed by their expectations of and familiarity with GIS inventory capabilities. Second, it seems that analytical techniques play a secondary role in problem-solving to process-driven techniques such as consensus building,

and negotiation which focus on human rather than objective dimensions of problem-solving. Finally, spatial analytical techniques specifically take a tertiary role to other techniques.

Data

The third set of research questions addressed the data component of Coastal SDSS by investigating:

- inventory requirements;
- the ability of GIS to accommodate the inventory requirements;
- the importance and appropriate evaluation of data quality; and
- the expectation of decision-makers towards the use of GIS in an inventory capacity for decision-making.

Availability and access to information was considered an important factor for coastal management. In several questions related to analytical and decision-making components, the need for a comprehensive database and effective communication thereof was raised. A coastal management inventory requires an extensive array of themes ranging from biological data, to socio-demographic data, to use patterns, and to administrative regime. Of these, those which have received least attention are the establishment of coastal use patterns and spatial representation of the administrative framework.

Data quality was not a pervasive issue raised by decision-makers throughout the research. It became evident, however, that decision-makers are aware of the delicate balance required between having sufficient data upon which to base decisions and having 'good' data. Participants seemed to be more aware of data quality issues in association with GIS. Some respondents noted that GIS lent a degree of objectivity and accuracy to the data. However, more respondents commented that quality control is diminished when using GIS, and that GIS can shroud and hide data quality issues with 'smoke and mirrors'. Nevertheless, the most prevalent strengths of GIS identified were inventory related including the ability to integrate diverse data sets and to facilitate their graphic display.

8.3 TOWARDS A COASTAL SDSS

The final set of research questions addressed the compilation of each of the preceding three components (decision-making, analysis and data) into Coastal SDSS. Specifically, this included the role of Coastal SDSS in coastal management and decision-makers' expectations of Coastal SDSS. This culminated in twenty-one design and implementation specifications for Coastal SDSS.

Decision-makers were cautious about embracing a central role for Coastal SDSS in decision-making. Due to their primary experience with GIS, a coastal SDSS was seen as a data warehouse although the potential for exploring 'what-if' scenarios was noted. When given three choices of implementing a Coastal SDSS in a decision-making process, respondents chose that which required least interaction between decision-makers and a system. This is attributed to the perceived experience required to use a system, the potential to promote an uneven playing field, and the potential to create a technology-driven process to the detriment of human factors.

The specifications derived from the research focused on implementation and the three components of a Coastal SDSS. Specifications were framed within a role of Coastal SDSS in which they are used to respond to and direct areas of investigation, rather than lead the process. The manner of inquiry with Coastal SDSS is geared towards facilitating the choice characteristics of coastal management decision-making.

System implementation is crucial to the effective use of a Coastal SDSS particularly in engendering support from potential users. Towards this aim, implementation specifications included a chauffeur-driven system at the decision-making table working in concert with a GIS facilitator, a one-day integrated education/data exploration workshop and a customised interface. The primary decision-making approach advocated is through generation and evaluation of alternatives, with an emphasis on the graphic communication of these alternatives.

The analytical tools specified in Section 7 work towards this goal of generating and evaluating alternative emphasising graphic communication. They include capability analysis, spatial coincidence and multiple criteria analysis. In addition, analytical functionality should be supplemented with existing models and software accessed through a common Coastal SDSS interface.

Data issues of Coastal SDSS indirectly have received much attention through developments in Coastal GIS. Outstanding issues specifically relating to Coastal SDSS include a taxonomy of coastal use, development of data themes on administrative responsibilities, a continuous terrain model of the coast and a metadata management strategy for data quality.

The debate between objective decision-making relying on analysis, and subjective decision-making relying on values, local knowledge, politics and negotiation, was raised throughout the research. At present it appears that coastal management is more politically than scientifically motivated. The lack of recognition or awareness of the potential of objective, and especially spatial, methodologies, for decision-making indicates a combination of a lack of education on behalf of the key players, and an historical lack of tools to facilitate objective decision-making. GIS and Coastal SDSS can respond to this void in spatial analysis. The question remains, however, whether emphasis should be placed on developing spatial analytical techniques, or on managing the more 'subjective' and political components of coastal management. It is clear that Coastal SDSS must address the balance between the two. On the one hand objective analytical solutions are sought to present unbiased and defensible solutions. On the other hand, such decisions cannot be made without consideration of the priorities and values held by the coastal community. Coastal SDSS can provide some of the analytical objectivity required particularly to narrow down a complex problem definition using spatial constraints. Subjective elements can be partially incorporated using weighted multiple criteria analysis and incorporating local knowledge and experience once the problem domain has been narrowed.

Throughout this dissertation reference has been made to three-dimensional and temporal modelling of the coast. This was raised in relation to environmental and process modelling, evaluating spatial coincidence, recording jurisdiction, and representing a continuous terrain. The incorporation of these parameters in a Coastal SDSS is also cause for debate. On the one hand, one could argue that coastal planning is firmly entrenched in customary two-

dimensional land use planning and decision-makers lack the background to address planning in the three-dimensional and temporal domains. On the other hand, the dynamic and continuous nature of the coastal environment cannot escape the attention of Coastal SDSS development. One of the goals of Coastal SDSS and modelling in general is simplification and abstraction. Incorporating the third and fourth domains may in fact be counter-productive to the simplification sought. But one must question the legitimacy of using tools and methodologies developed for an essentially two-dimensional static environment, for an environment which is inherently three dimensional and highly dynamic. The question remains as to how this dual-faceted debate can be addressed. What is the real need for three-dimensional and temporal domains within Coastal SDSS?

Today's GIS technology is not ready for the development of Coastal SDSS; nor is the technology ready for decision-makers. In addition, it is suggested that today's coastal decision-makers are not ready for a Coastal SDSS. Most notably, GIS lack the modelling capabilities to represent the true 3-D and 4-D complexity of the coastal environment. They also lack the real-time interactive and flexibility capabilities necessary for the generally undeterministic approach to decision-making. Decision-makers are struggling with, and some are dubious of, the capabilities of GIS beyond inventory storage and graphic display. Problem-solving skills and a need to think spatially require a shift in how decision-makers are prepared for the challenges of coastal management if decision-makers are to embrace the use of Coastal SDSS. The following question is therefore posed: is the technology premature for a field still trying to establish methodologies, or can the technology serve to instigate the development of these methodologies?

8.4 CALL FOR FURTHER RESEARCH

At the onset of this research, the development of a fully functional and networked Coastal SDSS was envisaged. This vision was tempered by the realities of available technology, decision-makers' expectations, and the numerous disciplines which must be consulted. Although significant progress has been made towards developing a Coastal SDSS, the larger contribution of this research has been to explore the issues that need to be taken into account and to provide directions for further pursuit. Each of the specifications presented in Section 7 is a potential avenue for further research. There are several specific areas, however, which deserve highlighting to further the progression towards an effective Coastal SDSS, assuming that there is sufficient desire by the key players involved in the decision-making process for the development of such a tool.

One of the more interesting and challenging areas requiring attention in the inventory component of Coastal SDSS is the development of a methodology to map the governance framework in terms of legislation, resources and activities. Second, a methodology to incorporate 3-D and 4-D in Coastal SDSS which is relevant to decision-makers and planning is worthy of investigation. In addition, data quality, to a certain extent, has remained an open-ended question with two emerging perspectives pertaining to data quality and data quantity. Although a metadata strategy for managing data quality theoretically appears to be the most appropriate approach, this needs to be evaluated in practice. Further research is required to attempt to merge the two perspectives with specific relevance to the decision-makers.

This researcher proposes that the most pressing need in developing Coastal SDSS analytical functionality is to establish a coastal management toolbox. This will provide guidance to those developing coastal management plans and prevent continual 're-invention of the wheel'. In the immediate case, this requires more comprehensive and detailed accounting of the processes and procedures involved in coastal management. In addition, methods of incorporating the subjective elements of decision-making particularly stakeholder values, and local knowledge and experience need to be investigated in order that a Coastal SDSS can appropriately provide the balance between objective and subjective decision-making. This is particularly relevant to developing methodologies to explore alternative scenarios both interactively and modelled. In addition, methodologies for evaluating spatial and value consensus are required.

As important as advancing these areas of research is the manner in which they are undertaken. None of the above can come to practical fruition without the co-operation and understanding of the intended users, be they coastal managers or community stakeholders. Above all, the research endeavours prescribed above need to be undertaken in concert with prospective users including politicians, planners and members of the coastal community. Because of the wide-ranging disciplines which infiltrate the development of a Coastal SDSS, this research should ideally be undertaken by an interdisciplinary research team. Basta's (1990) call for applied experimental design in which decision-support tools and systems are implemented and evaluated in actual coastal management initiatives needs to be repeated here as not only a valid but necessary vehicle towards a Coastal SDSS. Finally, the educational process preparing key players for their role in decision-making should include in the curriculum awareness of GIS and SDSS. It should also include awareness of different scientific objective decision-making processes - their roles, procedures and functions. In conclusion, the conceptualisation and development of agreed-upon standards and procedures for data collection, analysis and problem solving for coastal management by coastal managers will provide the strongest foundation for a Coastal SDSS.

Notes:

1. Throughout this report, the acronym CSDSS refers to 'Collaborative Spatial Decision Support Systems' and CSDM refers to 'Collaborative Spatial Decision Making'. To avoid confusion, the coastal analogue is always referred to as Coastal SDSS.
2. First Nations is a term used to define the original aboriginal inhabitants of Canada.
3. The slide-bar interface allows the user to assign a weight to each criterion by sliding a 'ruler' on the computer screen to the appropriate location between a value of -100 to +100. Compatible criteria are assigned a positive weight, while incompatible criteria are assigned a negative weight. The absolute total must equal 100. Thus, for example, if one of the criterion selected is 'Upland Sensitive', it may be assigned a value of -20, reflecting its relatively significant incompatibility with float cabins. By contrast, 'Recreational boating' may be assinged a value of +15, indicating compatibility with float cabins.

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APPENDIX A - CAPTURING STAKEHOLDER VALUES

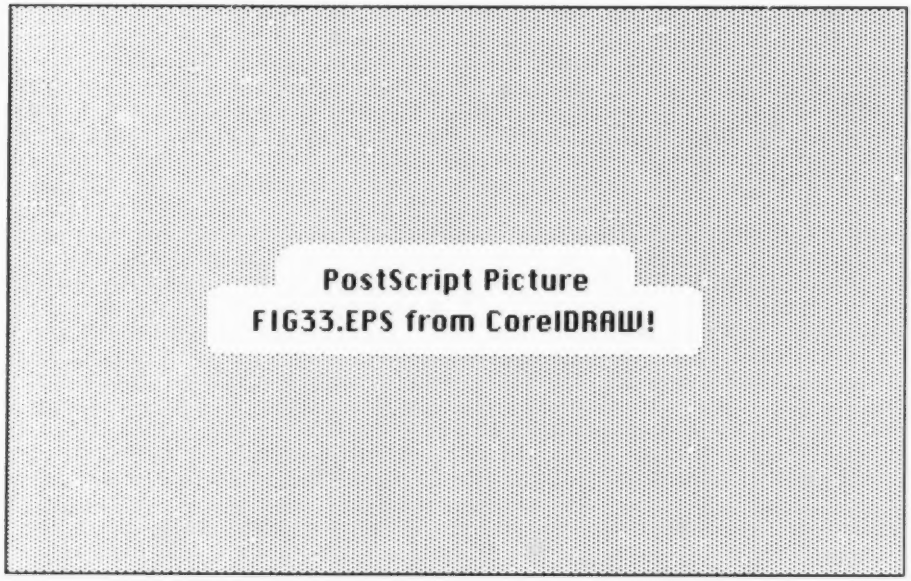
Various techniques have been developed to elicit stakeholder input with regards to preferences towards criteria and alternatives. These techniques can be divided into categories defined by the type of input, point or interval, and the scale of input measurement ordinal, interval or ratio (Figure 23). The most commonly used technique is to identify a point on an interval scale of preference or importance (Perreira and Duckstein, 1993; Easton *et al.*, 1992; Carver, 1991; Gardiner, 1981; Edwards, 1971). In most cases, decision-makers rate each element individually although Saaty's Analytical Hierarchy Process (AHP) employs pairwise comparison (Saaty, 1980). Other techniques require decision-makers to rank elements or place them into ranked categories (Bryson *et al.*, 1994; Voogd, 1981). While at the other end of the spectrum, decision-makers ascribe a single ratio value to the elements (Massam, 1980).

With respect to user input, it is easier to to assign an element to a category or rank preference than a unique cardinal value. However, although such input reveals which element is more important, there is no information gathered on how much more important one element is over another. Techniques to address these include normalising the eigenvector of the pairwise comparison matrix in AHP, assuming a ratio scale from ordinal ranking, ranking in an interval scale and implying ratios from the intervals, defining intervals for ranked categories and ordinal geometric evaluation (Bryson *et al*, 1994; Madu, 1994; Perreira and Duckstein, 1993; Gardiner, 1981; Voogd, 1981; Edwards, 1977).

Numerous potential problems exist when capturing stakeholder input and deriving a weighting scheme:

- lack of consistentcy in ratings; preference judgements consistently violate the axioms of rational choice (Seo and Sakawa, 1988; Tversky, 1977);
- decision-makers attach different meaning or interpretation to a value in a weighting scheme (Bryson *et al.* 1994);
- derived weights are not consistent with particpants' own expectations and preferences (Buchanan, 1994);
- ratings are made under conditions of uncertainty due to incompleteness and diversification of knowledge and information (Seo and Sakawa, 1988; Bryson *et al.*, 1994);
- techniques generally do not address this fuzziness and vagueness (Bryson *et al.*, 1994);
- decision-makers may be unwilling to identify a single value to represent their preference;
- values and preferences will change with attribute value and constraints (Tversky, 1977), and
- there are problems translating relative ratings of preference to degree of preference.

Figure 23: Input and measurement scales for stakeholder input



APPENDIX B - EVALUATING DECISION SUPPORT SYSTEMS

Effectiveness of decision support systems generally can be defined by the extent to which technology assists people in decision-making and problem solving (Sainfort *et al.* 1990). Assisting decision-making is often determined by *reaching* a *better* outcome *faster*. In the business sector, effectiveness and better decisions can be measured by the tangible benefits to the company such as reduced production cost, increased productivity and increased return of investment (Udo and Davis, 1992). Tangible benefits are less relevant to the types of decisions made in multiple use coastal management. Intangible or indirect benefits which are difficult to measure are assessed by substitute indicators which are not convincingly linked to actual benefits (Udo and Davis, 1992). In addition, very often the evaluation of effectiveness takes a technocentric view where effectiveness is primarily affected by the system capabilities in carrying out the decision steps. Increasingly, attention is being turned to the social view that the interaction and group dynamics equally contribute to decision effectiveness (Sambamurthy and Chin, 1994; Beauclair, 1989). Variables used to evaluate DSS effectiveness can be classified into (1) outcome variables; (2) process variables; (3) user variables; and (4) non-process variables.

Effectiveness measures

As surrogate measures for tangible benefits, a better decision can be measured by the perceptions of individuals concerning the outcome or resolution of the problem (Sainfort *et al.* 1990). The literature suggests several outcome variables:

- time taken (Buchanan, 1994; Beauclair, 1989)
- relevancy of output (Udo and Davis, 1992)
- completeness of output (Udo and Davis, 1992)
- level of post-meeting consensus (Sambamurthy and Chin, 1994)
- confidence in outcome (Sambamurthy and Chin, 1994; Buchanan, 1994)
- quality of outcome (Sambamurthy and Chin, 1994; Udo, 1992; Beauclair, 1989)
- general satisfaction with outcome (Sambamurthy and Chin, 1994; Beauclair, 1989)

This approach is product or outcome oriented. However, as Sainfort *et al.* (1990) argue, it is very difficult to determine the exact contribution of the DSS to the final outcome, since it is almost impossible to know what the same problem-solver in the same situation would have done without the DSS. Thus it is difficult to attribute effectiveness to the DSS as opposed to the general decision process itself.

Therefore, in addition to evaluating the outcome as a measure of effectiveness, there is a need to account for the problem-solving steps of the decision process (Beauclair, 1989; Sainfort *et al.* 1990). Accounting for process variables is especially relevant to this study where the emphasis is not on making a decision but rather on the exploration of alternatives. The decision process can be broadly divided into four steps: (1) problem structuring; (2) alternative generation; (3) evaluation and choice; and (4) implementation. Steps 1 and 2 and the first part of Step 3 are of particular relevant to this study. Identification of process variables is based on common assumptions made of what contributes to better decisions. From the literature the following list of process variables to measure effectiveness can be gathered:

Problem structuring:

- perceived importance of the problem (Sainfort *et al.*, 1990)
- problem understanding (Sainfort *et al.*, 1990)
- understanding other's views (Sainfort *et al.*, 1990)
- main area of conflict (Sainfort *et al.*, 1990)
- pre-meeting agreement

Alternative generation:

- number of alternatives (Sainfort et al., 1990)
- overall quality of alternatives (Sainfort et al., 1990)
- number of iterations (Buchanan, 1994)

Evaluation and choice:

- clarity of choice strategies (Sainfort *et al.*, 1990)
- ability to capture preferences (Buchanan, 1994)

Group process:

- proclivity to participate (Beauclair, 1988)
- quality of each person's interactions (Beauclair, 1988)
- extensiveness of use (Sambamurthy and Chin, 1994; Udo, 1992; Udo and Davis, 1992)
- integration of system (Sambamurthy and Chin, 1994)
- extent of team work

There is continuing debate on whether frequency of use of a system is a suitable measure of effectiveness (Sambamurthy and Chin, 1994; Udo and Davis, 1992).

The experience, perceptions and attitudes which participants bring to the table can influence the use and effectiveness of the system (Sambamurthy and Chin, 1994). Despite this, studies which examine the extent of influence of users' experiences, perceptions and attitudes are scarce and conflicting. Older (in age) users tend to result in more effective use of the system (Udo and Davis, 1992). Some studies show that unfamiliarity with computers can reduce the use and effectiveness of DSS (Beauclair, 1989). Other studies show that experience and education can both, positively and negatively influence use, satisfaction and overall effectiveness (Udo and Davis, 1992).

In addition to technical dexterity, it also has been shown that users' perceptions and attitudes can influence the process and outcome. Those with positive attitudes and expectations towards the use of the system are generally more satisfied and result in more effective use of the system (Udo and Davis, 1992).

User variables measured to evaluate effectiveness include:

- gender (Sainfort *et al.*, 1990)
- age (Udo and Davis, 1992; Sainfort *et al.*, 1990)
- education (Udo and Davis, 1992; Sainfort *et al.*, 1990)

- computer literacy (Beauclair, 1989)
- technical knowledge of the system (Udo and Davis, 1992)
- user expectations (Udo and Davis, 1992)
- attitudes towards DSS (Udo and Davis, 1992)

There are additional factors which are not directly related to the decision-making process but still can influence the effectiveness of the DSS. First among these non-process system attributes is ease of use. The more user-friendly a system is the more likely it is to be used and the more useful it is perceived to be (Sambamurthy and Chin, 1994; Davis, 1989).

Evaluation methods

There are various methods used to collect information which measure the above criteria of effectiveness. These include subjective participant judgement, non-participant observation, expert observation and objective measurement.

Subjective judgement involves the assessment of the system by the participants. Most researchers, particularly those using field studies, use self-report questionnaires completed by the participants (Udo, 1992). These questionnaires require participants to score using Liker-type scales, their experiences, perceptions and attitudes which capture their assessment of the system of subjective criteria such as preference to solutions, usefulness, user-friendliness and confidence in decisions. This questionnaire is normally administered immediately following the exercise.

In evaluating a decision support system, it is important to evaluate the effect the system has on the users and the decision process. In order to establish causal relationships or detect benefits/change as a result of using the system one must capture baseline information prior to using the system (Sainfort *et al.*, 1990; Sambamurthy and Chin, 1994). Thus a pre-test can be administered to capture information on elements of the decision process, initial level of consensus, awareness of the decision problem and level of interest and commitment to joint resolution. Information also can be gathered on a pre-test regarding participants' attitudes towards using a decision support system. In addition, the pre-test is used to collect background information on the participants which determine the independent variables of the system evaluation. These might include age, level of education, previous training and position in organisation.

Although less-often used, verbal feedback by participants can be useful to gather feedback from the participants (Buchanan, 1994; Beauclair, 1989). Verbal feedback can be either acquired throughout the process or immediately following. Gathering feedback throughout the process has the advantage of being more immediate therefore participants' evaluations are more likely to be freshest in their minds. However, this approach might also detract from the focus and flow of the decision-making task. Post exercise individual interviews or group discussion may be less distractive.

Non-participant observers can supplement the assessment made by particpants. They can either observe the proceedings directly or through video using a structured or unstructured observation format. By observing individual particpants, they can get a feel for level of frustration and frequency with which a particpant required technical assistance. They can also be used to evaluate the frequency of contributions by individual particpants (Beauclair, 1989). Perhaps, more importantly, non-particpant observers have the opportunity to examine the group as whole in the broader picture of the exercise, thereby taking note of general flow of the proceedings, group dynamics, domination or subordination by participants.

In some cases experts can be called in to evaluate the exercise or some aspect of it. These might involve experts in the field of the application, decision-making processes or computerised decision-making. For example, Beauclair (1989) used expert judges to evaluate the quality of decisions made by the decision-makers.

Finally, objective measurement can be conducted. This includes timing various stages of the process and determining the number of iterations undertaken.

APPENDIX C - COASTAL INVENTORY TAXONOMY

NATURAL ENVIRONMENT	
PHYSICAL	Bathymetry/terrain Coastal zone classification/Habitats (wetlands; lagoons; beach; tidal flats; salt marshes; mangroves, estuaries) Coastal drainage basins/Watershed boundaries Erosion/accretion Geology (bedrock, surficial, shore-zone; bottom sediments) Landslide hazards Fault lines Stream classification Shoreline type
OCEANOGRAPHY	Current (patterns; speed; surface; bottom) Circulation Freshwater runoff Mixing and upwelling Salinity Sea level change Storm events Stream flow Temperature Tides (flow; range; extremes) Water quality (faecal coliform; trace metals) Wave characteristics Wave exposure
WILDLIFE and PLANTS	Coastal fringe vegetation Birds (shorebirds; seabirds; waterfowl; raptors; nesting, feeding, migration, endangered) Biomass productivity Crustacea Fish (species; spawning, nursery; feeding areas; migration; endangered) Marine mammals (feeding; breeding; migration; haulout; endangered) Marine plants (species; stands) Nutrient loading Phytoplankton (primary productivity; red tide/blooms) Shellfish (species; grounds) Shore-associated mammals Stream productive capacity Terrestrial mammals Zooplankton

METEOROLOGY	Precipitation Temperature Visibility Wind

HUMAN USE ENVIRONMENT	
DEMOGRAPHICS	Employment Migration Populations Settlements
BIOLOGICAL RESOURCE EXTRACTION	Aquaculture (species, production; potential) Commercial fisheries (types/season; closure areas; landing areas; landings) Crustacea Forestry Marine plant harvesting Shellfish (closure areas) Subsistence fisheries (types/season; closure areas; landing areas; landings)
MINERAL RESOURCE EXTRACTION	Desalination plants Gravel Hydrocarbon Sand
CULTURAL RESOURCES	Archaeological First Nations traditional use Historic Land claims
ENERGY	Tidal Wave
INDUSTRY	Commercial Dredging Electric plants Fish processing plants Fuel storage Land fill Log handling / storage Mineral extraction Offshore oil and gas platforms Pulp and paper facilities Refineries
WASTE DISPOSAL	Dump sites (dredge; nuclear) Industrial outfalls Land fills Municipal sewage outfalls Wastewater outfalls Wastewater treatment facilities

MILITARY	Ammunition dump sites Exercise areas

HUMAN USE ENVIRONMENT (cont.)	
RECREATION and TOURISM	Beach combing Boast charters Boat racing Camping Capability, Capacity and Market Potential Hunting Kayaking Marina Public access Recreational boating (pleasure; racing regattas) Scenic features Snorkelling Sport diving Sport fishing (types/season; closure areas; landings areas) Swimming Visual landscape
RESEARCH	
SHIPPING, NAVIGATION and TRANSPORTATION	Cables Emergency anchorage areas Ferry (terminal; routes) Harbours/ports (facilities) Light houses Marina Navigational aids Oil spill contingency plans Piers Private moorage Railway Rights of way Roads Shipping routes Shore-zone access Wharves Wreck and salvage

GOVERNANCE	
BOUNDARIES	Department districts (*i.e.* forestry, environment) Fishing zones International maritime and land boundaries Territorial seas Zoning by-laws
GOVERNMENT and AGENCY RESPONSIBILITIES	Jurisdiction Federal Provincial/state Regional/Municipal Agencies/Departments
LEGISLATION	
TENURE	Lease (*i.e.* hydrocarbon, aquaculture) Military Native reserves Private
COMMUNITY PROGRAMS	
SPECIAL STATUS AREAS	Ecological reserves National parks Provincial/state parks Regional parks Sanctuaries Wildlife refuges World heritage areas

This taxonomy is compiled from information gathered in a literature survey and from questionnaire responses. Taxonomies on the Natural Environment are generally currently well-established. This research partciularly expands on taxonomies for Human Use and Governance.